AUTOMOBILE IGNITION, STARTING, LIGHTING

HAYWARD

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AUTOMOBILE IGNITION, STARTING, AND LIGHTING

A Comprehensive Analysis of the Complete Electrical Equipment of the Modern Automobile, Including Many Wiring Diagrams and Details of All the Important Starting-Lighting Systems

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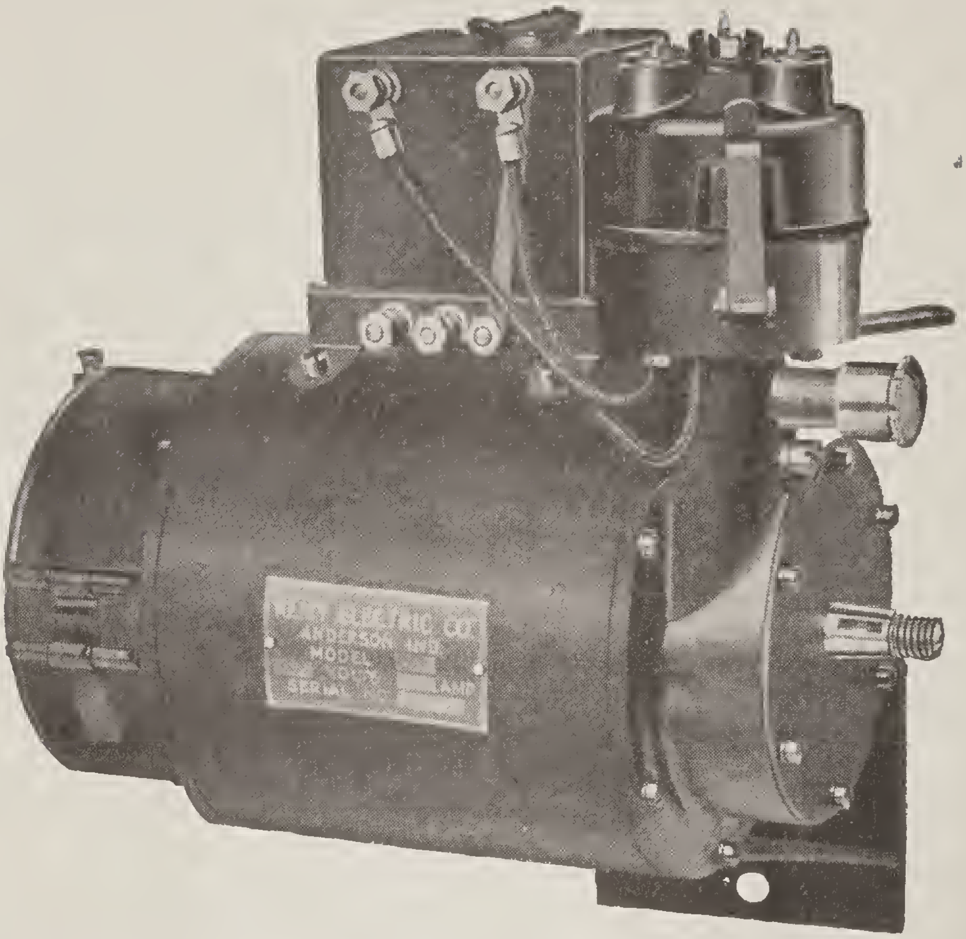
INTRODUCTION

THE fact that less than five years ago self-starters on automobiles were practically unknown shows how quickly this device has caught the public fancy. Many systems using springs and other mechanical devices, compressed air, and electricity were evolved, but the ease of coupling electric starting with lighting was too great to be ignored, and the electric system alone has survived. Electric starting-lighting systems demanded a generator as part of the equipment of every car, and the presence of this source of current had an almost immediate influence on the standing of the much favored magneto for ignition purposes. Just as a matter of economy, it seemed desirable to have the generator charge the storage battery, and thus indirectly supply the current for ignition as well as for starting and lighting. Many, however, have clung to the reliable magneto, and this has resulted in the use by the various makers of either the one-unit, two-unit, or three-unit systems, a condition which has gained nothing in simplicity by this evolution.

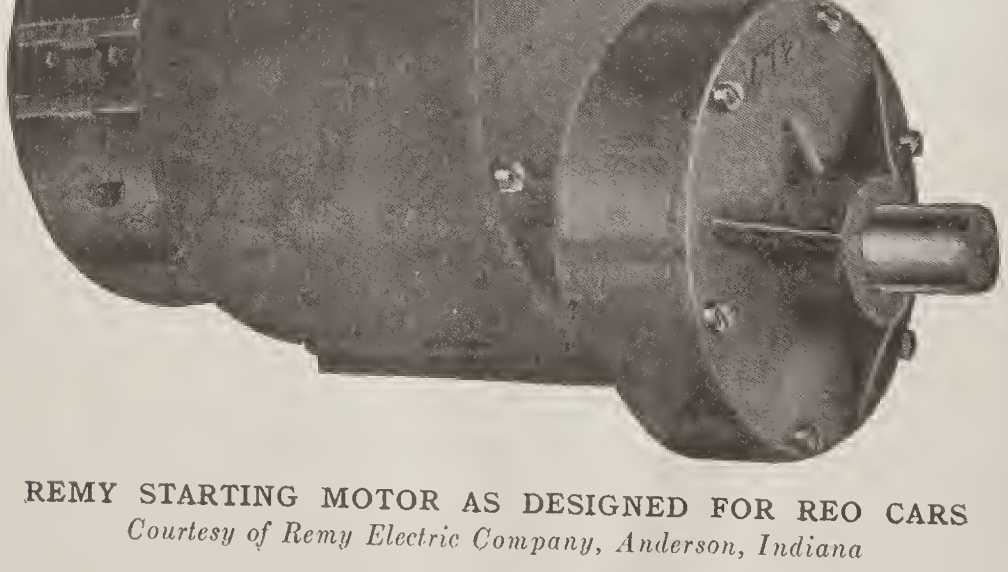
¶ The self-starter developments have also resulted in a large increase in the number and difficulty of the electrical problems which the repair man in particular is called upon to solve. He has had to add many unfamiliar terms to his vocabulary, and has had to find out how to trace the wires in the starting circuit, test for grounds or for a burned-out armature, and acquire more than a general insight into the behavior of the electric circuit under all sorts of conditions.

¶ These difficulties have led to an insistent call for a thorough and up-to-date treatise on the different starting-lighting systems, which demand, the publishers hope, will be abundantly satisfied by this handy volume. The author, who for years has been very closely associated with automobile and electrical affairs, has tried to present his material to meet the needs of the general reader and, at the same time, reach the difficulties of the repair man. For the latter classification, the wiring diagrams have been carefully analyzed and full instructions have been given for the various types. The discussion of the earlier as well as the latest models of each particular system and the variations of the same system on different cars should be particularly helpful.

¶ The placing on the market of a number of well-designed and inexpensive starters for Ford cars has been recognized by the insertion of a section entirely devoted to these types. Another new section on the care of the storage battery will enable repair men and individual owners to properly handle this very essential but much neglected part of the electric equipment.



IGNITION GENERATOR AS DESIGNED FOR REO CARS
Courtesy of Remy Electric Company, Anderson, Indiana



REMY STARTING MOTOR AS DESIGNED FOR REO CARS
Courtesy of Remy Electric Company, Anderson, Indiana

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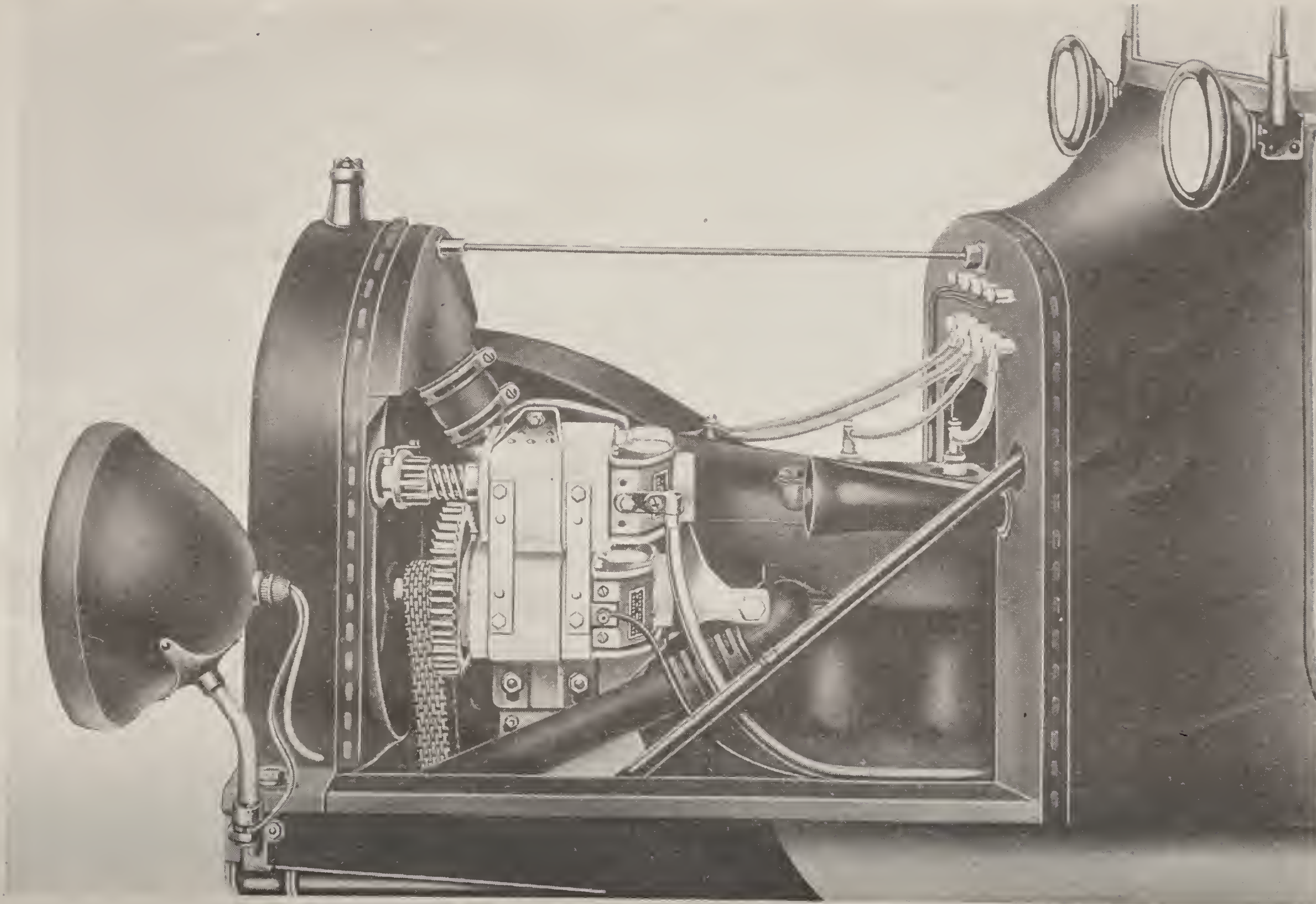


GRAY AND DAVIS STARTING AND LIGHTING INSTALLATION ON FORD CARS

Courtesy of Gray and Davis, Boston, Massachusetts

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART I

INTRODUCTION

Importance of Electricity on Automobiles. Starting with nothing more than a few dry cells and a wiring system that would have shamed an itinerant bellhanger, the electrical equipment of the automobile has constantly increased in importance, until within the last few years it has become the most essential auxiliary there is on the machine. Electricity now starts the motor, ignites the charge in the cylinders, lights the car and the road ahead, sounds the horn, and in some instances shifts the gears and applies the brakes. In addition to performing the numerous functions already mentioned, it has even gone as far as to displace the flywheel, clutch, and gearset altogether, in which case the car is provided with as many gradations of speed as a steam car. It seems quite likely that along this line is to be one of the most important developments of the next few years.

Inherent Weakness of Electrical Devices. Even in the present highly perfected state, the electrical equipment still constitutes the weakest element among the motor auxiliaries. In fact, it is subject to more frequent defection than any other single element of the entire construction of the automobile. This must not be taken as implying that it is defective in any sense, as it is quite the contrary, ignition, lighting, and self-starting systems having been developed to a degree of reliability that was undreamed of in the earlier days. But owing to its nature, the electrical equipment is more susceptible to derangement. Consequently, a rather substantial proportion of the minor troubles of automobile operation that still survive to harass the motorist arise from some failure of the electrical system. Of course, many of these are due to the inexperience or ignorance of the motorist himself, and for this reason it behooves the student

to give more than the usual amount of attention and study to this branch of the subject.

ELEMENTARY ELECTRICAL PRINCIPLES

Knowledge of Principles Necessary. To acquire a good practical working knowledge of electricity as applied to the automobile today, it is essential not merely to find out *how* things are done, either by watching the other fellow do them, or by studying "pictures in a book", but also to learn *why* certain things are done and *why* they are carried out in just such a way. In other words, the man whose knowledge is based upon theory and principles applies knowingly the cause to produce the effect and is certain that the desired effect will be produced. On the other hand, the man who works only with his hands aimlessly goes from one thing to another trusting chiefly to luck to accomplish two things. One of these is to strike upon the remedy for the trouble the cause of which is sought, and the other is to deceive the spectator—usually the owner of the car—into believing that the fumbler really knows what he is about.

There are accordingly two distinct classes of knowledge as regards the electrical equipment of an automobile—one which is picked up by rote, an isolated point at a time, and applied in the same manner, and the other which is based upon a clear insight into the underlying reasons for the various actions and reactions that make up the different electrical phenomena involved. If we want to know what is wrong with an electric motor, it is essential that we should know what makes an electric motor operate when everything is right. In the same way, it would be groping in the dark to attempt to investigate the reasons for the failure of a dynamo to generate current, or a storage battery to give up its charge, if we had no knowledge of why a dynamo, when run by an outside source of energy, normally produces a current, or why an accumulator literally "gives back" what has been put into it when its circuit is closed after charging.

It will accordingly be the function of this introductory chapter to give a brief résumé of the principles underlying the operation of what has come to be the most important auxiliary of the gasoline motor as applied to the automobile—its electrical equipment.

A thorough understanding of these principles will go a long way toward enabling one to remedy the various minor ills that afflict the apparatus, and to recognize at once those of a nature serious enough to be beyond the first aid which even the best equipped garage is capable of giving. It is worse than a waste of time to hunt for a short circuit or a ground as the cause of failure of the dynamo to generate, when an inspection of its parts reveals the fact that its armature winding has been burned out. Again, one can hardly expect the motor to continue starting the gasoline engine when the owner's neglect of the storage battery has permitted the plates to sulphate so badly that they are practically worthless. Contempt of "book knowledge" is not wholly a thing of the past, and many men consider themselves "practical" in insisting upon learning how to do things with their hands alone. The best-paid man, however, and he who can instruct others how things should be done, is the man who uses his head to acquire a knowledge of the theory upon which practice is based, and then employs his hands to much better effect by letting his brain guide them.

THE ELECTRIC CIRCUIT

Current. Just what electricity is we do not know—maybe we never shall know—but it is a matter of common knowledge that it is one of nature's prime forces and as such is universal. The air, the earth, the water, the clouds, our bodies and those of animals, as well as inanimate objects such as trees, houses, and the like are all electrified to a greater or less degree all the time. The amount of electricity that any given object possesses at a given moment depends upon its capacity (the electrical meaning of which is given later) and the conditions of surrounding objects. For example, a room will hold a certain amount of air; if it is uninfluenced by other conditions, we know that the room is full of air at an approximate atmospheric pressure of 15 pounds to the square inch (the usual pressure at sea level). The room may be considered in a normal "state of charge".

There is nothing that differentiates the air in this room from that of the room adjoining. It is perfectly quiet and nothing is disturbing it; there is no tendency for it to move. If, however, all the openings of the room are tightly closed with the exception

of a duct for the admission of more air under the impulse of a powerful compressor, in a very short time there will be a marked difference between the air in this room and the air in the other rooms. Instead of the normal atmospheric pressure of 15 pounds per square inch, there will be a pressure against all parts of the room—floor, walls, and ceiling—of 50, 60, or 100 pounds, according to the length of time the compressor has been working and the degree of tightness with which the various openings have been closed. Thus there will be a great deal more air in the one room than in its neighbors. If it were electricity instead of air, the room would be said to be highly charged.

The air in this room, on account of the pressure which it is under, is constantly seeking an outlet, and it will gradually leak out through various small openings, probably without its escape being noticed. The same conditions obtain when a body becomes electrified beyond its capacity to hold a charge—the charge of electricity will leak away without giving any indication of its passing. Turning again to the room containing the compressed air, if a door or window of that room is opened suddenly, the pressure is immediately released through that opening and anyone standing in front of it would say that a strong current of air blew out. In the case of electricity, if any easy path of escape is provided, the entire charge will rush away from the body, and there is then said to be a current of electricity "flowing" from this point of escape to whatever other object equalizes the pressure by becoming charged. An electric current is accordingly electricity in motion; it is simply said to flow. But to cause it to do so there must be pressure. The electrical term for this pressure is *potential* or *voltage*.

Electrical Pressure. Every day in the year the earth transmits a greater or less proportion of its electrical charge to the atmosphere, or receives a charge from the latter, but unless the conditions are favorable there is no visible indication of this *difference of potential* as it is termed. It must be borne in mind that this difference of potential, or difference in electrical pressure, between two points is what causes a current to flow. Given a hot day in summer, however, when the air is heavily charged with moisture and low cumuli, or rain-charged clouds form in great masses, then the electrical charges from the earth and the air accumulate in these

great banks of dense water vapor instead of passing up to the higher regions of the atmosphere. When the charge exceeds the capacity of the clouds, and the electrical pressure, or difference of potential, between two neighboring clouds or between a cloud and the earth becomes very great, we have the familiar phenomenon of lightning, the electricity escaping in a several-mile-long flash instead of by means of the little spark with its snap as it passes from one object to another under similar conditions.

Resistance. It is thus apparent that electricity is an element that can be expressed as a quantity, and likewise one that can be subjected to pressure. The unit of current is the *ampere;* the unit of electrical pressure is the *volt;* the unit of quantity is the *coulomb,* equal to one ampere per second. Resuming the simile previously given, 500 cubic feet of air forced into the room under a pressure of 100 pounds to the square inch, may be likened to a current of 500 amperes at 100 volts. And, just as the opening allowed determines the quantity of air that will escape at a time, so the electrical outlet influences in the same manner the current that will flow. From this it is evident that there is another factor to be considered. This is resistance.

If a half-inch hole is bored in the door of the room, the air will escape at a pressure of 100 pounds to the square inch, but only a few cubic feet per minute can pass through the orifice. If a very fine wire is used to tap the given charge of 500 amperes at 100 volts, the current will have a potential of 100 volts, but very few amperes will pass through the fine wire. If the pressure back of the air is increased, however, more air will be forced through the small opening in the same time; and if there is a greater potential back of the electrical current, more current will be passed through the fine wire. Thus the factors of electrical quantity, pressure, and flow are all related and are all dependent on the factor of resistance. The unit of resistance is the *ohm.*

Ohm's Law. From this interrelation has been deduced what is known as Ohm's law, usually expressed as $I=\frac{E}{R}$, or current equals voltage divided by resistance, E denoting the electromotive force, which is only another term for voltage or potential—the electrical moving force back of the current I.

As a practical application of the preceding formula, take the case of a small conductor connecting the battery and starting motor of the electrical starting system on an automobile. The diameter of the wire is such that the length required to connect the two points has a resistance of 10 ohms. One ampere is that amount of current which will pass through a conductor having a resistance of one ohm under a pressure of one volt. The starting system in question operates at 6 volts. Hence, $I=\frac{6}{10}=.6$, that is, the battery would be able to force only .6 ampere through that small wire, and the starting motor would not operate.

It is apparent from the foregoing that the formula for Ohm's law may be transposed to find any one of the three factors that may be unknown. For example, given the conditions just mentioned, we may determine how much resistance the wire in question has. The resistance equals the voltage divided by the current: that is, $R=\frac{E}{I}$, or resistance equals $\frac{6}{.6}=10$ ohms. Or again, if it is desired to learn what voltage is necessary to send a current of .6 ampere through a resistance of 10 ohms, the solution calls for an equally simple transposition of the formula. Given any two factors, then the third may be readily determined.

Ohm's law is absolutely fundamental in all things pertaining to electrical operation, and the man who wants to make his knowledge of the greatest practical use will do well to familiarize himself with it. Naturally it does not enter into repair work to more than a small fraction of the extent that it enters into the design of motors, generators, and other electrical devices, but a knowledge of it is of distinct value.

Power Unit. To go back to the simile of air under pressure, it is apparent that the energy released by the lowering of this pressure may be made to perform useful work, such as driving a compressed-air drill, running a small air motor, or the like. So with the electric circuit, the drop from a higher to a lower potential, which causes a current to flow, is a source of power. Electrical power is the product of the amperage or current multiplied by the voltage at which it is applied. The power unit is the *watt* and it is equivalent to one ampere of current flowing under a pressure, or potential, of one volt. There are 746 watts in a horsepower.

Electrical computations, however, are based on the metric system to a large extent, so that instead of being figured in horsepower, electrical energy is figured by the kilowatt, or a unit containing one thousand watts, and the charge therefor is based upon the length of time for which this amount of energy is employed. From this comes the now familiar expression "kilowatt-hour".

The power equivalent is expressed as $P = I \times E$, current multiplied by electromotive force (potential), and, as in the case of Ohm's law, with any two of the factors given, the third may be readily determined. For example: How much power is developed by a 6-volt starting motor if 125 amperes of current are necessary to turn the automobile engine over fast enough to start it? The amount of current given is an arbitrary average taken simply for the purpose of illustration, for in overcoming the inertia of an automobile engine a great deal of current is required at first, the drain on the battery often exceeding 250 amperes for a few seconds, then dropping as the engine turns over to about 50 or 60 amperes. Taking 125 as the average, we have $125 \times 6 = 750$ watts $= .75$ kilowatt, or slightly over one horsepower.

Granting that one horsepower is necessary to turn over a $3\frac{1}{2}$ by 4-inch six-cylinder motor at 75 r.p.m.—a speed that has been predetermined as necessary to cause it to take up its own cycle under the most adverse starting conditions—and given a 6-cell storage battery capable of developing a potential of 12 volts, then we have: $I = \frac{P}{E}$, or current $= \frac{746}{12} = 62.1+$ amperes, which represent the average demand upon the storage battery to start that engine under normal conditions. This illustration and the previous one show the working of Ohm's law; doubling the voltage halves the amount of current necessary. As the life of a storage battery is largely determined by the rapidity as well as by the number of its discharges, and as the storage battery is the weakest element in any electric lighting-and-starting system, it may well be asked why the 12-volt standard is not universally adopted, or why, as is done in some cases, a 24-volt battery is not employed and the current consumption again reduced by half. Just why this is not done is explained in detail in the section on the voltages employed in electric starters generally.

Conductors. To lead steam or air under pressure from a boiler or compressed-air reservoir to the point at which it is to be utilized as energy, it is desirable to use a conductor that will not waste too much of this energy in useless friction. That is, the conductor must be of ample size in proportion to the volume to be conveyed, smooth in bore, and free from sharp turns or bends. The transmission of electrical energy involves some of the same factors. While neither the smoothness of the bore nor the presence of bends and turns has any effect, they have their counterpart in the conductivity of the material of which the wire is made, the size of the wire in proportion to the amount of current to be carried being also a matter of prime importance.

Resistance of Materials. Materials differ greatly in their ability to conduct an electric current, or, to put it the other way around, they differ in the amount of resistance that they offer to the passage of the current. Silver in its pure state heads the list in the table of relative conductivities, and it is accordingly said to possess a relative resistance of one, or unity; the resistance of every other material may be expressed by a number which represents the resistance of that particular substance as compared with pure silver. Naturally silver does not represent a great possibility for commercial use, and so copper, which is second on the list, is almost universally employed. Pure copper is very soft and is lacking in tensile strength; it is therefore alloyed, and it is also hardened in the drawing process; both of these processes increase its resistance slightly over the factor usually accorded it in the standard table of specific conductivities of materials. In this table, German silver (which is an alloy containing no silver whatever and having but a few of its properties), cast iron, steel, carbon, and similar substances will be found well down toward the end. They are known as "high-resistance" conductors and are usually used where a certain amount of resistance to the current is desirable.

It must be borne in mind that ability to conduct a given amount of current without undue loss through resistance depends upon the size and the length of the conductor quite as much as upon the material. In other words, if a steel rail is only one-thirtieth as good a conductor as a copper cable, it will require a cross-section of steel thirty times as great as that of a copper cable in order to

conduct the current with the same ease—that is, to make a conductor of equal resistance. An illustration of this may be seen in the overhead copper wire of the usual trolley system. This wire of about one-half inch diameter forms one of the conductors, while the two steel rails form the "return". A similar example may be found in what is known as the single-wire system of installation for an electric starter in automobiles. A single copper cable conducts the current from the battery to the starting motor, while the steel frame of the automobile is the return side of the circuit, or vice versa.

Voltage Drop. It is evident that the resistance of a circuit varies inversely as the size of the conductor—the larger the cross-section of a conductor, the less its resistance—and increases directly as its length, besides depending upon the specific resistance of the material. The specific resistance of the metals constituting electrical circuits on the automobile are (silver being 1.0); copper 1.13, varying more or less with its hardness; aluminum 2.0; soft iron 7.40; and hard steel 21.0. Thus, 9.35 feet of No. 30 copper wire are required for a resistance of one ohm, while only 5.9 inches of hard steel wire of the same gage are required to present the same amount of resistance to the current. If the length of the conductor is doubled, its resistance is doubled, which accounts for the placing of the storage battery as close as possible to the starting motor. Furthermore, the heavy starting currents which are required by the motor demand the use of heavy copper cable for this circuit. If two wires are of the same length but one has a cross-section three times that of the other, the resistance of the former is but one-third that of the latter. If a circuit is made up of several different materials of different sizes joined in series with one another, the total resistance will be the sum of the resistance of the various parts.

In addition to being affected by the cross-section and the length, the resistance is also influenced by the temperature. All metals increase in resistance with an increase in temperature, that of copper increasing approximately .22 per cent per degree Fahrenheit. The change of resistance of one ohm per degree change in temperature for a substance is termed its *temperature coefficient*. Metals have a positive temperature coefficient; some materials, like carbon,

have a negative temperature coefficient, that is, they decrease in resistance with an increase in temperature.

It is consequently necessary to employ wires of proper size to carry the amount of current required by the apparatus in circuit —such as lamps—without undue heating, which would cut down the amount of current flowing. For the same reason it is also desirable to make the circuits as short as practicable, since in addition to cutting down the current, the resistance also cuts down the effective voltage. That is, there is a fall of potential, or drop in voltage, between the source of current supply and the apparatus utilizing it, due to the resistance of the conductors between them. This voltage drop is further increased by joints in the wiring and by switches. It is apparent that the lower the voltage of the source of supply, the more important it becomes to minimize the loss, or voltage drop, in the various circuits. For this reason lighting or other circuits on the automobile should never be lengthened where avoidable. When necessary to extend a circuit for any reason, wire of the same diameter and character of insulation as that forming the original circuit must be employed, and the joints should be as few as possible, all mechanically tight, and well soldered. The voltages employed in the electrical systems of automobiles are so low—varying from 6 to 24 volts, with a strong tendency to standardize the 6-volt system—that any increased resistance is likely to cause unsatisfactory operation.

Non-Conductors. In going down through a table of specific conductivities of various materials, the vanishing point is reached with those that cease to be conductors at all. Such materials are known as nonconductors or insulators, and some substances vary in the degree of insulation they afford quite as much as other materials do in their ability to conduct a current. Glass, rubber, shellac, oil, paraffin wax, wood, and fabrics are all good insulators when perfectly dry. Distilled water has such a high resistance as to be almost an insulator, but in its natural state water contains alkaline salts or other impurities that make it a conductor. Consequently, when any otherwise good insulating substance is wet, the current is likely to leak across the wet surface of the insulator. This is particularly the case with a current of high potential, or high tension, and explains why it is of the greatest importance

to keep all parts of the secondary side of the ignition system perfectly dry. The potential which causes the current to arc across the gap of the spark plug is so high that it will leak across even slightly damp surfaces, such as the porcelains of the plugs. This leakage is often visible, especially in the dark, and it may also be detected by placing the bare hand on the porcelain.

Just as the amount of current to be carried determines the size of the conductor to be employed, so the potential or pressure under which this current is transmitted determines the amount of insulation that will be necessary. The latter is also affected, however, by mechanical reasons, for example, by the liability of the conductor to chafing or abrasion. The best grades of copper cable employed for both ignition and starting-lighting systems on automobiles today are stranded, that is, composed of a number of fine wires, to make them flexible. The stranded cable is then tinned to prevent corrosion due to the sulphur in the insulation, after which it is covered with a soft-rubber compound of a thickness dependent upon the purpose for which the wire is intended. For high-tension ignition wiring this rubber covering will be fully one-half inch thick. This covering is vulcanized and is then further protected by braided linen, or silk-cotton thread which is made waterproof by being impregnated with shellac or some other insulating compound.

Circuits. When air under high pressure escapes from its container, it simply mingles with the atmosphere, and as soon as the difference in pressure is equalized there is no distinction between it and air in general. But to equalize a difference in potential of an electric current there must be a conducting path between the points of high and low potential. This is termed a circuit. Current to operate trolley cars is fed to the motors of the car from the overhead wire and returns through the tracks to the generators at the power house. This is known as a *ground-return* circuit. In the single-wire electric starting system of an automobile, current from the storage battery reaches the starting motor through the starting switch and a single heavy cable, and returns through the frame and other metal parts of the car itself, or *vice versa*. This is another instance of a ground-return circuit.

Both the primary and secondary sides of the ignition system of an automobile are also grounded circuits. In contrast with

this, the circuit may be composed of copper cables directly connecting both poles of the battery and switch with the starting motor. The highly insulated cable employed for both ignition and starting systems is expensive and the use of a single wire greatly simplifies the connections, considerations which account for the general use of this type of circuit. A circuit is said to be open when there is a break in it which prevents the current from flowing, as

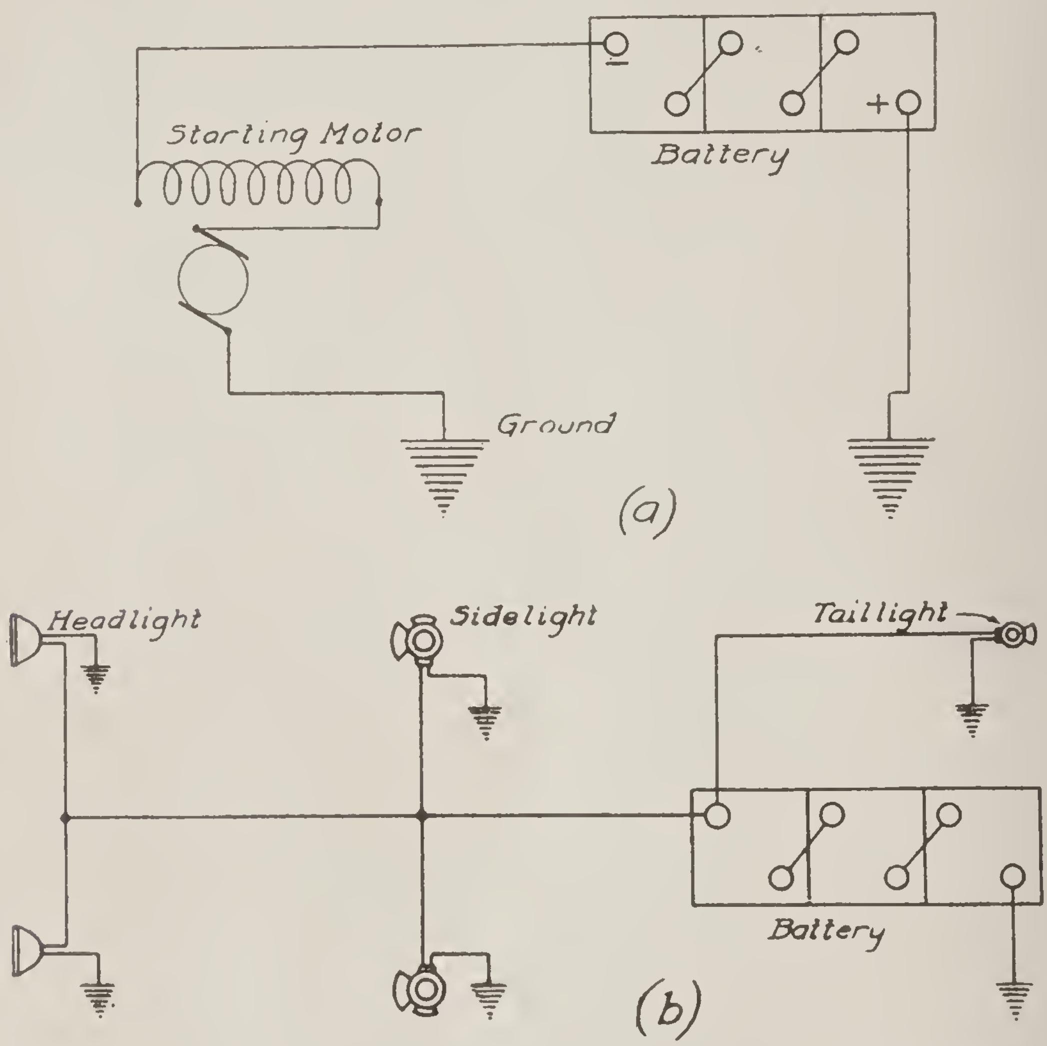


Fig. 1. Typical Starting-Lighting Wiring Diagrams. (a) Series Circuit of Starting Motor; (b) Multiple Circuit of Lamps

when the switch is opened, or when a connection or the wire itself is broken.

Series Circuit. The connections between a storage battery, switch, and starting motor, comprise the simplest form of circuit, in which the motor is said to be in series with the battery, and the cells of the battery are in series with one another. This is termed a series circuit and a break in it at any point opens the entire circuit. The starting motor, Fig. 1 (a), requires the entire output of the storage battery for its operation.

To make clear the distinction between this and other forms of circuit, it must be borne in mind that, in equalizing a potential difference, electric current flows from the positive or plus side of the source of supply, whether a battery or generator, to the negative or minus side (plus and minus being arbitrary signs employed to distinguish the positive and negative sides of a circuit or of an instrument). The current is said to flow out on the positive side of the circuit and to return on the negative side. In the case of a series circuit as described, the current flows through each piece of apparatus in turn; each receives all the current in the circuit at a potential proportioned to the resistance of the apparatus in question. For example, in the simple starter circuit referred to above the starting motor receives the entire output of the 3-cell storage battery at its full voltage of 6 volts, less the drop in voltage due to the resistance of the circuit. If there were two starting motors instead of one in the circuit, both in series, both would receive all the current but at only half the voltage.

Multiple or Shunt Circuit. As opposed to this, in a multiple circuit, Fig. 1 (b), in which every piece of apparatus is connected to both sides of the circuit "in parallel", each piece of apparatus in the circuit receives current at the same voltage but draws from the circuit the current determined by its resistance. The failure or withdrawal of any one or more instruments in a multiple or parallel circuit has no effect on those remaining. The lighting circuits of an automobile equipped with a 6-volt starting system are an example of this. Each lamp is designed to burn to its maximum illumination at 6 volts, but the 25-candle-power headlights take more current than the 5-candle-power side lights or the 2-candle-power taillight, owing to the difference in the size and resistance of their filaments. Removing any one of the bulbs has no effect on any of the others, because all are in parallel.

Series-Multiple Circuit. A combination of the two forms of circuits is sometimes necessary to accommodate different devices designed for varying voltages. For example, it is usually found expedient to burn 6-volt lamps on the 12-volt starting systems. In such a case, the starting motor is in series with the battery and receives the full voltage as well as the full current. The lamps are divided into two groups, each group comprising a parallel or mul-

tiple circuit of its own, and these two groups are connected in series so that the lamps in each circuit receive 6 volts, but the circuit as a whole takes the battery current at 12 volts. Such a combination

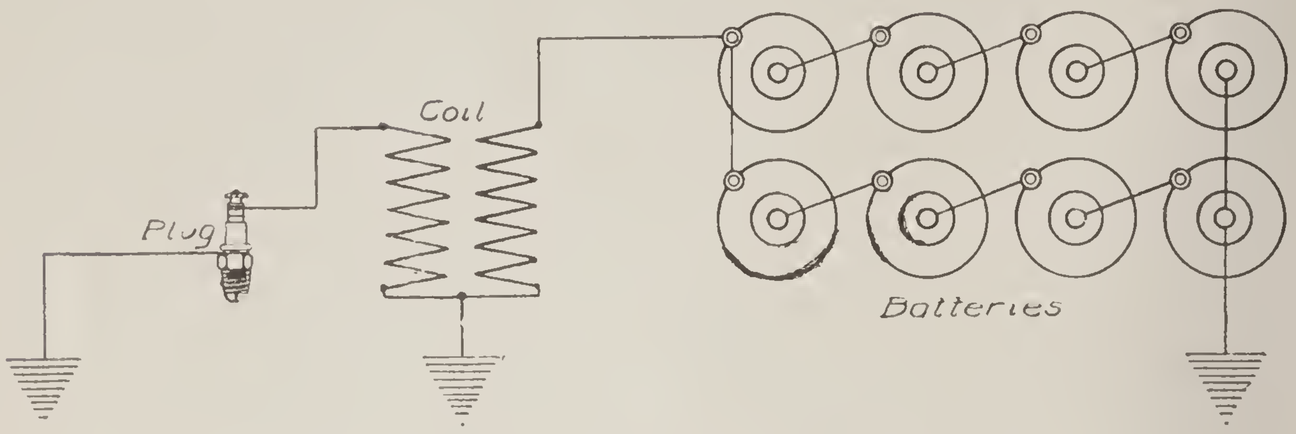


Fig. 2. Dry Cells in Series-Multiple for Ignition Circuit

is known as a series-parallel or series-multiple circuit and is more or less commonly used for connecting dry cells for ignition use, Fig. 2.

Circuits may also be interdependent, that is, practically a circuit on a circuit. The method of connecting up the voltmeter that is mounted on the dash of the car is an instance of this, a wire being led from each side of the main circuit to the instrument. The instrument is then said to be *in shunt*, Fig. 3, and the amount of current that is diverted to it is entirely dependent on the resistance. As a voltmeter is wound to a high resistance, Fig. 4, it is designed to take very little current for its operation. The

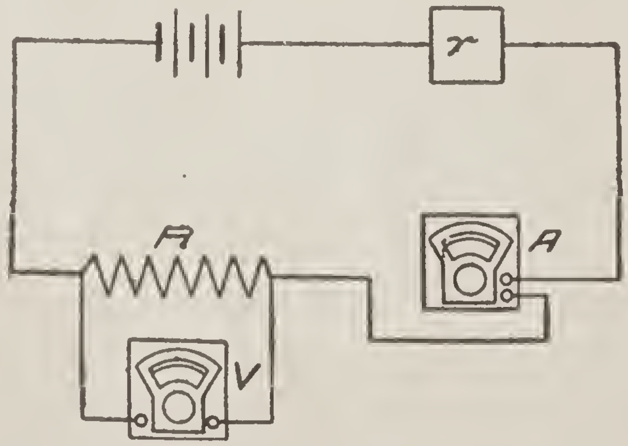


Fig. 3. Diagram Showing How Voltmeter Is Shunted in the Circuit

ammeter, Fig. 5, on the other hand, is intended to indicate the entire current output of the generator on charge or discharge, and is accordingly connected in series so that all the current passes through

it. (Owing to the heavy rush of current taken by a starting motor in overcoming the inertia of the gasoline engine, the ammeter is not included in this circuit.)

Short-Circuits and Grounds. The previous paragraphs have made clear the necessity for having a complete path or circuit for the current in order that its power may be utilized. There must be a connecting cable on one side and there must be a return on the other (grounded circuit). If instead of passing through the apparatus, such as the starting motor, the current finds an easier path through an abrasion in the insulation of the cable and some metal part against which that touches, it is said to be *short-circuited*. A case such as that cited, where a stripped cable touches a metal part, so that the current completes the circuit without passing through the motor, is usually termed a *ground*. This should not be confused with the ground return previously mentioned as a characteristic of the wiring of many of the starting and lighting systems in use on automobiles today. It is indeed a ground return but not an intentional one. It is also true that a ground of this type is a short circuit, but it does not necessarily follow from this that

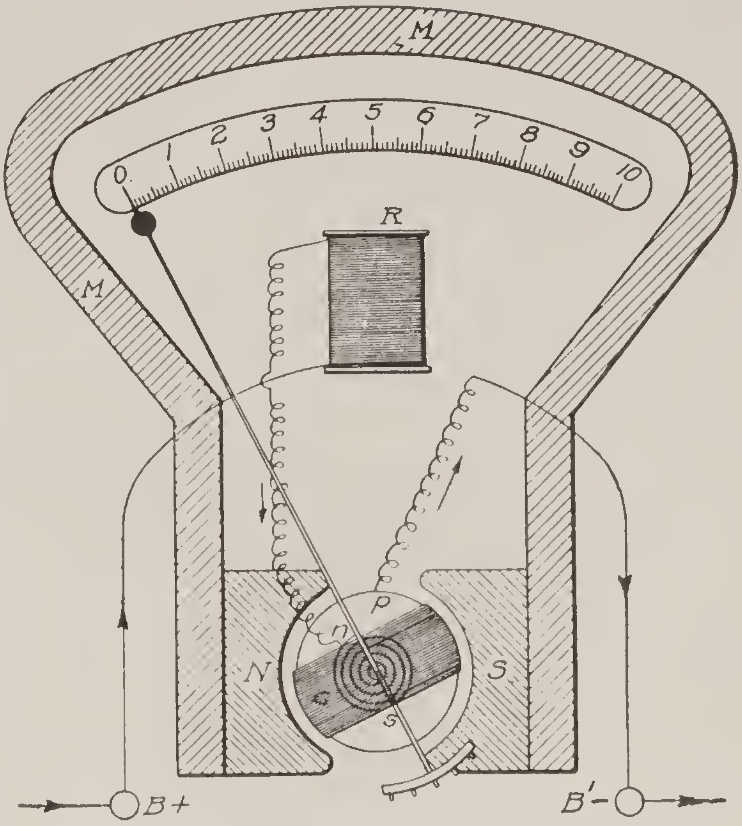


Fig. 4. Diagram of Voltmeter Principle

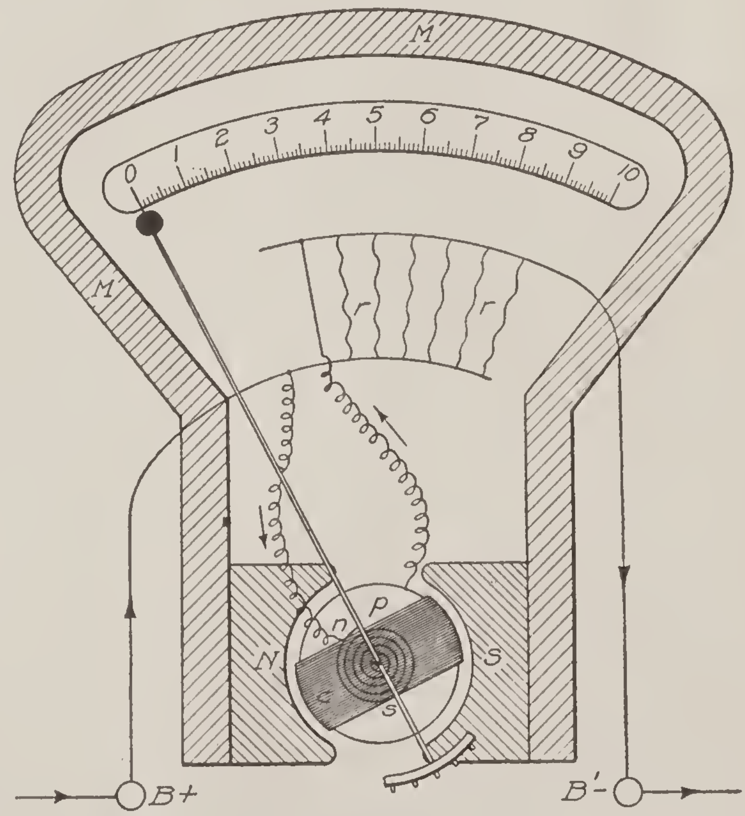


Fig. 5. Diagram of Ammeter Principle

all short circuits are grounds, as short circuits may occur from many other causes—for instance, where two wires touch at uninsulated points or where stray metal makes contact with connections, etc.

Size of Conductors. The influence of the factor of resistance makes plain the reason for using wires of different sizes for the various circuits of the ignition starting and lighting systems of the automobile. If an ample flow of compressed air is desired for power purposes, a liberal outlet must be provided, while if only a small spray is required, as for cleaning purposes, a small-bore tube will suffice. If we try to employ the small-tube line for power purposes, we shall not gain the desired result because its resistance is so great that it will not permit a sufficient flow of air. For the same reason a conductor of much larger diameter and, therefore, of correspondingly low resistance must be employed to handle the heavy current necessary to operate the electric starting motor, than is needed for the comparatively small current which is demanded by the ignition system.

Whether it is mechanical or electrical in its nature, the power necessary to overcome resistance is liberated in the form of heat. Mechanical resistance is friction and its presence between moving bodies always generates heat. Electrical resistance may, for the purpose of illustration, be termed internal or molecular friction, and it also results in heat. The extent of the rise in temperature of a conductor or wire, depends entirely upon the proportion that its size and, consequently, its current-carrying ability bear to the amount of current that is sent through it. Roughly speaking, if a wire is three-fourths the size it should be to carry the starting current, it will become uncomfortably warm to the hand after the motor has been operated several times in succession. If it is only one-half the size it should be, continuous operation of the starting motor for a few minutes will doubtless burn off most of the insulation. Further reducing its size would cause the wire to become so hot as to set fire to the insulation the moment the current was turned on, and any great decrease in diameter would result in the immediate fusing of the wire itself. The wire would literally "burn up" and in a flash.

It would not be practical to attempt to conduct live steam

TABLE I

American Wire Gage (B. & S.)

No.	Diameter in		Circular Mils	Ohms per 1000 Ft.	No.	Diameter in		Circular Mils	Ohms per 1000 Ft.
	Mils	Mm.				Mils	Mm.		
0000	460.00	11.684	211600.0	.051	19	35.89	.912	1288.0	8.617
000	409.64	10.405	167805.0	.064	20	31.96	.812	1021.5	10.566
00	364.80	9.266	133079.4	.081	21	28.46	.723	810.1	13.323
0	324.95	8.254	105592.5	.102	22	25.35	.644	642.7	16.799
1	289.30	7.348	83694.2	.129	23	22.57	.573	509.5	21.185
2	257.63	6.544	66373.0	.163	24	20.10	.511	404.0	26.713
3	229.42	5.827	52634.0	.205	25	17.90	.455	320.4	33.684
4	204.31	5.189	41742.0	.259	26	15.94	.405	254.0	42.477
5	181.94	4.621	33102.0	.326	27	14.19	.361	201.5	53.563
6	162.02	4.115	26250.5	.411	28	12.64	.321	159.8	67.542
7	144.28	3.665	20816.0	.519	29	11.26	.286	126.7	85.170
8	128.49	3.264	16509.0	.654	30	10.03	.255	100.5	107.391
9	114.43	2.907	13094.0	.824	31	8.93	.277	79.7	135.402
10	101.89	2.588	10381.0	1.040	32	7.95	.202	63.2	170.765
11	90.74	2.305	8234.0	1.311	33	7.08	.108	50.1	215.312
12	80.81	2.053	6529.9	1.653	34	6.30	.160	39.7	271.583
13	71.96	1.828	5178.4	2.084	35	5.61	.143	31.5	342.433
14	64.08	1.628	4106.8	2.628	36	5.00	.127	25.0	431.712
15	57.07	1.450	3256 7	3.314	37	4.45	.113	19.8	544.287
16	50.82	1.291	2582.9	4.179	38	3.96	.101	15.7	686.511
17	45.26	1.150	2048.2	5.269	39	3.53	.090	12.5	865.046
18	40.30	1.024	1624.1	6.645	40	3.14	.080	9.9	1091.865

at high pressure through a cardboard tube. Nor is it any more so to attempt to send a heavy current through "any old piece of wire". Electric lighting and starting systems as they exist on cars today are of all degrees of merit. The cars themselves have reached a stage of reliability where their useful life is now on the average from five to ten years or more. Consequently, there are a great many cars in service equipped with electric systems that were brought out several years ago. These are the cars on which the repair man will get a great deal of his early experience, and he need not take it for granted that just because the electric systems have worked for a certain length of time they were properly designed at the outset. Overheated conductors not only indicate excessive resistance caused by small wires or poor joints, but they also indicate a waste of power that is being drawn from the battery and dissipated in the air. The utilization of this energy or rather the prevention of its transformation into heat would mean all the difference between poor and good operation between an efficient and a wasteful system.

Heating Effect of Current. The amount of heat that a given current will produce in passing through a conductor of a certain size is expressed by Joule's law: The number of heat units developed in a conductor is proportionate to its resistance, to the square of the current, and to the time that the current lasts.

The heat generated, therefore, increases in direct proportion to the resistance. For example, if the cable between the starting motor and the battery be replaced by one-half its size, the resistance will be doubled and the heat generated will increase in the same proportion, the current remaining the same in both instances. Increasing the current, however, adds to the amount of heat generated, as the square of the increase. Thus, if with the original starting cable above mentioned, the amount of current necessary to start the motor has to be doubled, owing to gummed lubricating oil or stiff bearings, the volume of heat generated will increase fourfold. The amount of heat generated also increases in direct proportion to the time that the current lasts. It will be easy to realize from this why abnormal conditions may quickly bring the heating effect of the current to a point where the insulation of the wires, or even the wires themselves, may be endangered. For instance, in the case of a motor that is very hard to start, the discharge from the battery is greatly increased in turning it over, and the starting motor must be operated for a very much longer period to get the engine under way, causing a direct increase in the heating effect, due to the longer time that the current is passing through the cable, and a fourfold increase for the additional current necessary.

Heat Generated in Starting Motor. Take the case of a motor that requires 150 amperes for the first few seconds and 50 amperes once the engine is turning over freely. If stiff bearings or gummed oil cause the initial current to rise to 200 amperes and the running current to 80 amperes for a period three times as long as would ordinarily be required to start, there will be a very considerable increase in the number of heat units generated. This is one of the reasons why it is good practice to use the starting motor intermittently when the engine does not at once fire and take up its own cycle, instead of running the starting motor continuously until the engine begins to fire and generate its own power. A much more important reason, however, is the fact that the intermittent use of the starting motor

is not nearly so hard on the battery, as the storage battery recuperates very quickly when given short periods of rest between the demands for its power. Running the starting motor for ten periods of 30 seconds each, with a like interval between the attempts to start, will not discharge the battery anything like as much as will operating the starting motor continuously for five minutes. A longer rest between trials will be of greater benefit to the battery.

Heating Effect on Lamps and Fuses. It must not be concluded from the above that the heating effect of the current is always detrimental, as it is taken advantage of in many ways. Two of the commonest of these are the incandescent lamp and the fuse. In the case of the former, the increase in heat with an increase in resistance is mainly depended upon, the filament being made of such a size that a given amount of current at a certain voltage will just bring it to incandescence. For this reason an increase in the current, or voltage, will burn the filament and destroy the lamp. The fact that the heating effect increases as the square of the current is taken advantage of in the design of fuses which are made of soft alloys that will melt at comparatively low temperatures. Resistance is also a factor in the fuse, as in cutting down the cross-section of the fusible wire the resistance is increased, while the current-carrying capacity of the wire is decreased. The cross-section, or diameter, of the fuse is gaged to carry the amount of current that is a safe load for the circuit and the apparatus in it plus a reasonable factor of safety to prevent the fuse from burning out, with a small percentage of increase that would do no damage. For example, a 10-ampere fuse, such as is used in connection with many automobile-lighting generators, would seldom burn out with an increase in the current to 12 amperes or even to 15 amperes for short periods, as the time element is also important. Some other applications of the heating effect are electric welding, blasting fuses, soldering coppers, cooking utensils, and the like.

Chemical Effect of Current. The passage of an electric current likewise has a chemical effect depending upon the nature of the conductor. This may take various forms, such as the conversion of one chemical compound into another, as in the case of the storage battery; the decomposition of water into hydrogen and oxygen; the deposition of metals, as in electroplating; or the decomposition of metals, as in electrolysis.

TABLE II

Carrying Capacity of Wires

B. & S. Gage	Circular Mils	Rubber Insulation	Other Insulation
		Amperes	Amperes
18	1,624	3	5
16	2,583	6	8
14	4,107	12	16
12	6,530	17	23
10	10,380	24	32
8	16,510	33	46
6	26,250	46	65
5	33,100	54	77
4	41,740	65	92
3	52,630	76	110
2	66,370	90	131
1	83,690	107	156
0	105,500	127	185
00	133,100	150	220
000	167,800	177	262
0000	211,600	210	312

MAGNETISM

Natural and Artificial Magnets. It has been known for many centuries that some specimens of the ore known as magnetite (Fe_3O_4) have the property of attracting small bits of iron and steel, Fig. 6. This ore probably received its name from the fact that it is abundant in the province of Magnesia in Thessaly, although the Latin writer Pliny says that the word magnet is derived from the name of the Greek shepherd Magnes, who, on the top of Mount Ida, observed the attraction of a large stone for his iron crook. Pieces of ore which exhibit this attractive property for iron or steel are known as natural magnets.

Fig. 6. Natural Magnet or Lodestone

It was also known to the ancients that artificial magnets could be made by stroking pieces of steel with natural magnets, but it was not until the twelfth

century that the discovery was made that a suspended magnet would assume a north-and-south position. Because of this property, natural magnets came to be known as lodestones (leading stones); and magnets, either artificial or natural, began to be used for determining directions. The first mention of the use of a compass in Europe was in 1190. It is thought to have been introduced from China.

Fig. 7. Bar Magnet

Artificial magnets are now made either by repeatedly stroking a bar of steel, first from the middle to one extremity with one of the ends, or poles, of a magnet, and then from the middle to the other extremity with the other pole; or else by passing electric currents about the bar in a manner to be described later. The form shown in Fig. 7 is called a bar magnet, that shown in Fig. 8 is a horseshoe magnet.

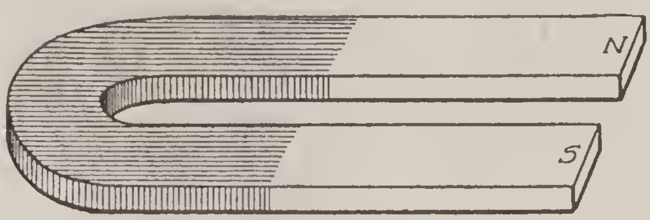


Fig. 8. Horseshoe Magnet

Poles of a Magnet. If a magnet is dipped into iron filings, the filings are observed to cling in tufts near the ends, but scarcely at all near the middle, Fig. 9. These places near the ends of the magnet, in which its strength seems to be concentrated, are called the poles of the magnet. It has been decided to call the end of a freely suspended magnet which points to the north, the north-seeking, or north pole, and it is commonly designated by the letter N. The other end is called the south-seeking, or south pole, and is designated by the letter S. The direction in which the compass needle points is called the *magnetic meridian.*

Fig. 9. Location of Poles of a Magnet

Laws of Magnetic Attraction and Repulsion. In the experiment with the iron filings no particular difference was observed between

the action of the two poles. That there is a difference, however, may be shown by experimenting with two magnets, either of which may be suspended, Fig. 10. If two N poles are brought near each other, each is found to repel the other. The S poles likewise are found to act in the same way. But the N pole of one magnet is found to be attracted by the S pole of the other. The results of these experiments may be summarized in the general law: *Magnet poles of like kind repel each other, while poles of unlike kind attract.*

This force of attraction or repulsion between poles is found, like gravitation, to vary inversely as the square of the distance between the poles; that is, separating two poles to twice their original distance reduces the force acting between them to one-fourth its original value, and separating them three times their original distance reduces the force to one-ninth its original value, etc.

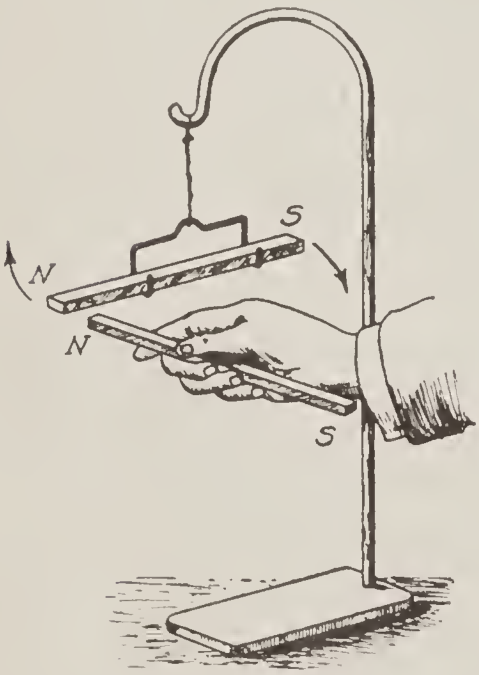


Fig. 10. Experiment Proving the Law of Magnetic Attraction and Repulsion

Magnetic Substances. Iron and steel are the only common substances which exhibit magnetic properties to a marked degree. Nickel and cobalt, however, are also attracted appreciably by strong magnets. Bismuth, antimony, and a number of other substances are actually repelled instead of attracted, but the repulsion is very small. Until quite recently, iron and steel were the only substances whose magnetic properties were sufficiently strong to make them of any value as magnets. Recently, however, it has been discovered that it is possible to make rather strongly magnetic alloys out of non-magnetic materials. For example, a mixture of 65 per cent copper, 27 per cent manganese, and 8 per cent aluminum is rather strongly magnetic. These are known as the *Heussler alloys.*

Electromagnets. The identity of magnetism with electricity is readily established by some very simple experiments that have been repeated so often as to become classics. By taking a bar of iron and winding some insulated wire around it in the form of a coil and then connecting the terminals of this coil with a battery or other source of current, the bar becomes magnetic. One end

of it is the positive, plus, or north pole of the magnet, and the other the negative, minus, or south pole. Break the connections or otherwise "open the circuit" and the magnetism instantly disappears. Reverse the connections to the battery by attaching the wire previously at the positive pole to the negative, and vice versa, complete the circuit again, and the bar is once more magnetic, but now the pole that was previously north or positive is south. The bar is once more a magnet, but its polarity has been reversed by reversing the direction of flow of the magnetizing current. This bar of iron with a coil of wire wound around it is known as an electromagnet because it becomes magnetic only when a current is passing through the coil. If a rod of hard steel is substituted for the bar of soft iron and the current passed through it, the bar will be found to be strongly magnetic after the current has been shut off. That is, the bar of steel has, through the action of the current, become a permanent magnet like that shown in Fig. 7. This method is often used for making permanent magnets from hardened steel.

To determine the polarity of a magnet it is only necessary to hold a small pocket compass near it; let the compass needle come to rest normally and then bring the compass near to one end of the magnet. If the needle continues to point in the same direction and gives evidences of being strongly attracted to the magnet, the end to which it is being held is the south pole. Bring the compass near to the other end of the magnet, and the needle will turn away sharply, showing that like poles repel each other.

Magnetic Field. If a bar magnet is placed on a sheet of glass and a handful of fine iron filings thrown around it, they will automatically assume the position shown by Fig. 11. As originally dropped on the glass some of the filings may not be within reach of the influence of the magnet, but if the glass be gently tapped and tilted slightly, first one way and then another, they will arrange themselves in the symmetrical pattern shown. This gives a graphic illustration of the *field of influence* of the magnet, usually termed the magnetic field. This field is most powerful at the poles, as will be noted by the attraction of the filings at the N and S points, representing the north and south poles of the magnet. At intermediate points along the length of the magnet the filings will be seen to have placed themselves as if to indicate a circular movement

of the lines of force. This is the magnetic circuit and these concentric circles represent the magnetic flux, or flow. If the magnet is then removed from the glass and the north pole extension of it placed

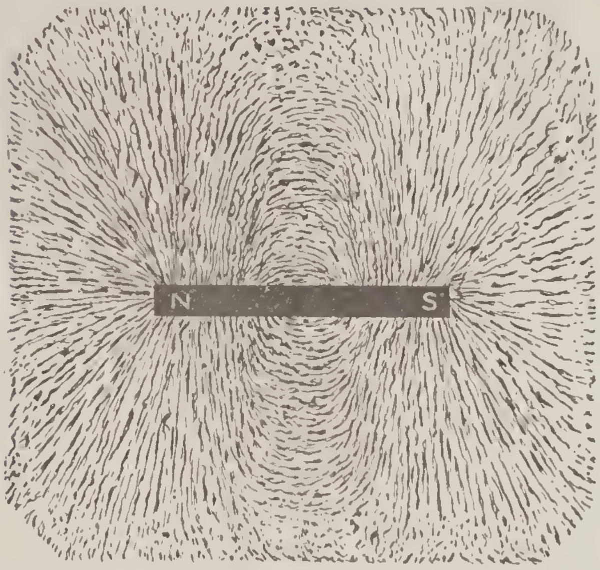


Fig. 11. Field of Force about a Bar Magnet

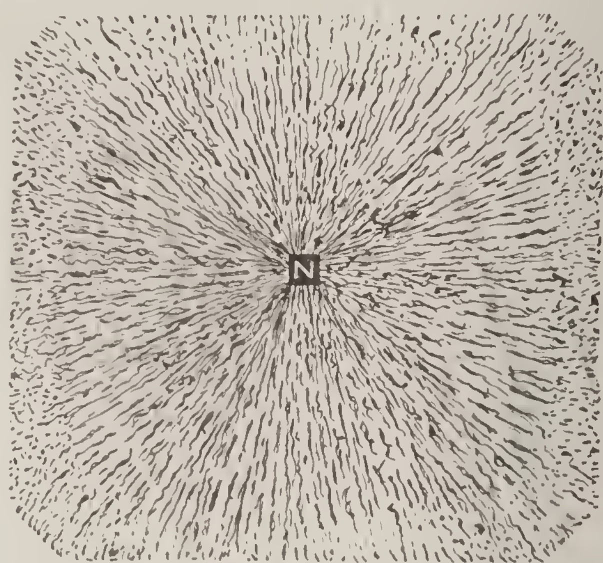


Fig. 12. Field of Force about a Single Pole

centrally under the glass, a striking illustration is given of the magnetic field around the pole, Fig. 12. A bar magnet has been shown here for purposes of simplicity, but a common horseshoe magnet such as can be had for a few cents will serve equally well for the experiments.

By carrying the experiments a little further, the identity of magnetism and electricity is strikingly shown. Take a piece of

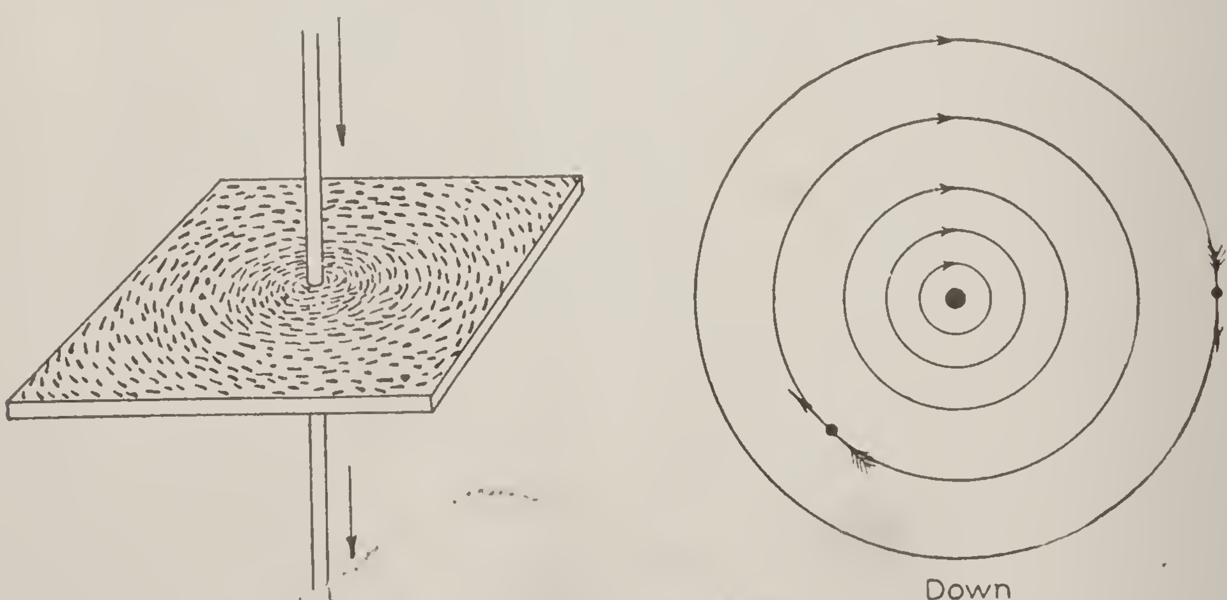


Fig. 13. Field about a Conductor Carrying a Current

cardboard or heavy paper, punch a hole through its center and pass through this hole a wire connected to two or three dry cells. Scatter on the paper the filings used in the previous experiments,

then complete the circuit by touching the end of the wire to the other terminal of the battery. The filings will immediately arrange themselves as shown in Fig. 13, illustrating the magnetic field which is always present around any current-carrying conductor.

Lines of Magnetic Force. Punch another hole through the cardboard and rearrange the circuit of the dry cells so that the wire passes from the positive battery terminal up through one hole of the cardboard and down through the other hole to the zinc or negative. Scatter the filings as before and touch the loose end of the wire to the negative terminal. The arrangement of the filings will then be that shown in Fig. 14, the positive field being at the left and the negative at the right. The fact that the magnetic fields overlap in the curious alignment indicated is simply due to the proximity of the conductors carrying the current.

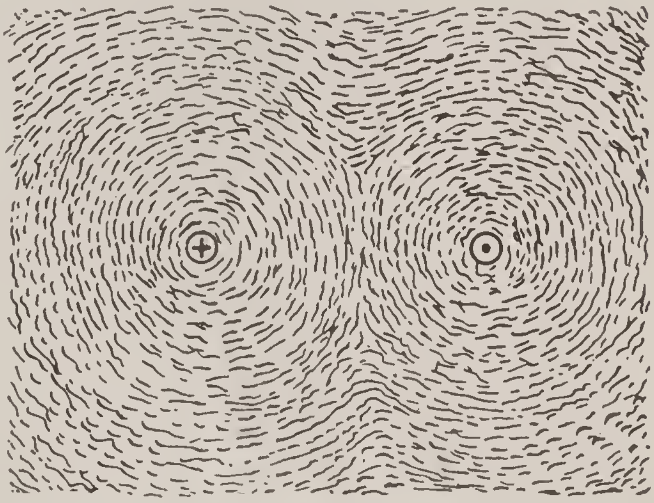


Fig. 14. Field about a Coil

Another simple method of demonstrating the identity of electricity and magnetism is to place an ordinary pocket compass near a wire carrying a current. If this is a direct current and the needle of the compass whirls around when its north pole is presented to the wire, it is evidence that the current in the wire is positive, since like poles repel. Present the other end of the needle and it will remain stationary even though the compass be shaken, since unlike poles attract. This experiment is accordingly a simple polarity test as well.

All of the arrangements which the filings assume under the influence of either a magnet or a current, as shown by the various llustrations, indicate that the stresses in the medium surrounding a magnet or current-carrying conductor follow certain definite lines, the lines showing the direction of stress at any point. These are termed lines of force.

Solenoids. It has been determined that the direction of the current and that of the resulting magnetic force are related to one another as the rotation and travel of an ordinary, or right-hand,

screw thread. Consequently, if the conductor be looped instead of straight, the lines of magnetic force will surround it as shown in Fig. 15. The field of such a loop, if outlined with the aid of filings or explored with a compass needle, will be seen to retain the general character of the field surrounding a straight conductor, so that all the lines will leave by one face and return by the other, the entire number passing through the loop. Hence one face of the loop will be equivalent to the north pole of a magnet and the other face to the south pole. In fact, the loop will act exactly as if it were a thin disk magnetized perpendicularly to the plane. By winding a number of these loops to make a hollow coil, there is formed a solenoid, Fig. 16. Exploring its field shows that the lines of force pass directly through the center or opening of the hollow coil, leaving by one end and returning by the opposite end, as indicated.

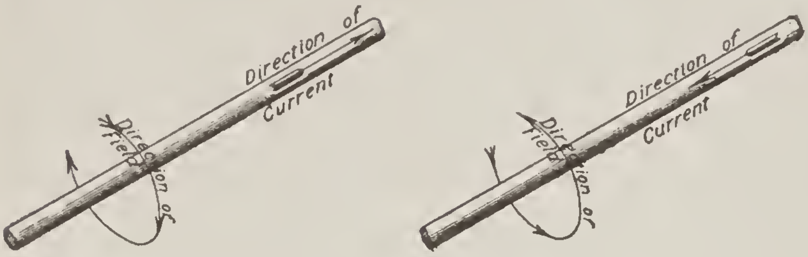


Fig. 15. Direction of Magnetic Lines about a Conductor

If such a solenoid is held vertically and a bar of soft iron placed so that it extends for an inch or so into the lower end of the solenoid, a current passed through the latter will cause the iron to be violently drawn up into the coil and held there. As long as the current flows, this rod is strongly magnetic and has all the properties already described. But the moment the current is shut off, the magnetism practically disappears and the rod immediately drops out of the coil by its own weight. Reversing the direction of the current reverses the polarity of the solenoid; increasing or decreasing the amount of current sent through it increases or decreases correspondingly the strength of its magnetic field. The principle of the solenoid is used in starting systems to operate electromagnetic starting switches.

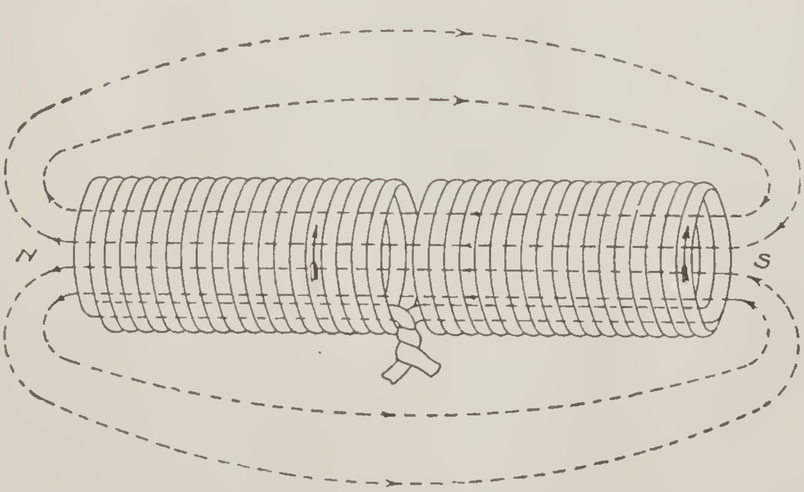


Fig. 16. Magnetic Field about a Solenoid

Effect of Iron Core on Strength of Solenoid. The magnetic flux or flow of lines of force through a solenoid is much greater when an iron core is present than when the coil is empty or a core of wood is inserted. The magnetism flows through the iron as a current would. Soft iron is said to have a high *magnetic permeability.* The magnetic permeability of air (or a vacuum) is taken as unity and other substances rated accordingly: for very soft iron it may be as high as 2500, while for substances such as silk, cotton, wood, glass, brass, copper, and lead, it is unity, the same as for air. Such metals are said to be non-magnetic. All insulators are likewise non-magnetic.

INDUCTION PRINCIPLES IN GENERATORS AND MOTORS

Induction. When a wire carrying a current is placed close to another wire, a delicate measuring instrument such as a galvanometer will indicate the presence of a current in the second wire. When the current in the first wire ceases, that in the second will likewise cease immediately. This phenomenon is known as induction, and a current is said to have been induced in the second wire.

Winding the first wire in the form of a coil and bringing this coil close to the second wire, will give the induced current considerably greater strength. The induced effect is still further increased in three other ways: *first,* by inserting an iron core in the coil; *second,* by winding the second wire in the form of a coil; and, *third,* by bringing these coils as close together as possible by winding one directly over the other.

Transformer Principle. The arrangement just discussed is termed an induction coil or transformer (step-up) and is universally employed in connection with ignition systems. The character of the induced current depends upon the relation that the first coil, termed the *primary,* bears to the second coil, known as the *secondary.* In the usual ignition coil the primary consists of a few turns of comparatively heavy wire, and a heavy current—10 to 20 amperes or more—is sent through it at a low voltage, one seldom exceeding 6 volts. The secondary coil, however, consists of a great number of turns of exceedingly fine wire, and the current induced in this is proportional to the relative number of turns between the two and the value of the current in the primary. The

secondary current is accordingly of extremely high potential but of only nominal current value.

In the commercial step-down transformer, the relations described above are reversed, the primary being a coil of many turns of fine wire, while the secondary is a comparatively small coil of few turns. In this case, the current is received at the transformer at high voltage and correspondingly reduced amperage, and it steps the voltage down to the standard generally employed, 110 or 220 volts, and increases the amount of current proportionately.

Self-Induction. It has already been pointed out that electricity may be put under pressure or potential, and that the greater this pressure, the greater the amount of work a certain amperage of current will perform, thus affording a direct analogy with steam, water, or air under pressure. An electric current also possesses other characteristics corresponding to mechanical equivalents. Chief among these is inertia and it is the latter that is responsible for what is known as self-induction.

When a current is passed through a coil of wire, a strong magnetic field is set up in the coil owing to the concentration of a great many turns of wire in a small compass. By inserting a core of soft iron wires into this coil, the magnetic field is greatly strengthened, since the permeability of the iron affords a path of slight resistance for the magnetic circuit. There is, of course, a magnetic field surrounding every conductor in a circuit when the current is passing, but the iron core of the solenoid converts a certain part of this current into magnetism. An appreciable time is necessary after the circuit is closed for such a coil "to build up". This "building up" consists of saturating the core with magnetism.

When the circuit is suddenly opened, the current that has been stored in this core in the form of magnetism is as quickly retransformed and its value is impressed upon the circuit, causing a flash at the break. The flash is also aggravated by a certain amount of inertia which the current possesses. We may illustrate this by a stream of water flowing in a pipe. If the water is suddenly shut off by the closing of a valve, it tends to keep on flowing and momentarily causes a great increase in the pressure against the face of the valve, resulting in the familiar "water hammer". The same thing happens when a circuit is suddenly broken, and the

higher the potential the more marked this effect will be. The current tends to keep on flowing, and the extra potential which this self-induction gives it will cause it to arc, or bridge, the gap at the break, unless a condenser is provided to take care of this. Every circuit possesses self-induction, but it is only marked in circuits having considerable inductance, that is, in coils, and especially those with iron cores, such as induction coils, circuit breakers, etc.

Capacity of Condensers. Every conductor of electricity has capacity to hold a charge just as a vessel holds water. But the capacity of a conductor is dependent upon its surface area rather than its cross-section, or cubic volume, and is also influenced by surrounding conditions. Where it is desired to accumulate a considerable charge, as for an ignition spark, a special form of capacity is utilized. This is known as a condenser (a detailed description of which is given later in connection with ignition coils). The ability of a condenser to absorb the rise in potential that occurs through self-induction whenever a circuit containing inductance is opened is also utilized to prevent sparking at contact points. Comparatively small condensers are necessary for this purpose, and they are shunted around the contact points, that is, connected in parallel with the latter. When the circuit is opened the excess energy of the circuit passes into the condenser instead of forming a hot spark at the contacts. The occurrence of any undue amount of sparking at contacts should accordingly be made the subject of an investigation of the condenser connections, or of the condenser itself.

Comparison of Generator Current to Water Flow. The comparison of air in a room has been made to illustrate the presence of electricity and its characteristics, since it may be made to partake of all the latter by being put under pressure, allowed to escape through various sized outlets, and made to perform work of differing nature by being utilized at varying pressures and volumes, exactly as electricity is. Where an electric current is produced by a generator, however, the older simile of water flowing under pressure due to the impulse of a pump may serve to make it much clearer. This comparison of a water pump and its piping with an electric generator and its circuits is known as a hydraulic analogue, and, it may be added, there is scarcely any characteristic or function of the electrical current that cannot be similarly compared.

Take, for example, a waterworks system of the type in which a large pump at the power house draws water from artesian wells or a reservoir and forces it into a closed system of piping. Located on this piping system are all the house outlets, street hydrants, and the like. The speed of the pump is regulated so as to keep a certain amount of pressure on the water in the pipes, based upon the average demand at different periods of the day. The pressure is reduced at night and is increased at any time, day or night, in case of fire.

Pressure and Voltage. This constant pressure in pounds per square inch that the pumps maintain on the supply of water in the entire piping system is the exact counterpart of the voltage, or electromotive force, produced by a dynamo, or generator, when running. Just as the pressure exerted on the water by the pumps depends upon the speed of the latter, so the voltage produced by the dynamo is proportional to its speed. In the case of the pump, the pressure depends upon the number of times that the pistons of the pump reciprocate; in the dynamo, upon the number of times that the coils, or windings, of the armature cut the lines of force of the magnetic field in which it revolves. This is explained in detail later in connection with generator principles.

When the pump moves very slowly, there is very little pressure produced in the pipes, and this is the case with the dynamo to an even greater extent, since dynamos are usually designed to run at very much higher speeds, and consequently their voltage, or pressure, drops off very sharply at low speeds. This will explain why the majority of lighting generators on automobiles do not begin to charge the battery until the motor of the car is running at a speed equivalent to ten to fifteen miles per hour, as explained later. At low speeds they do not generate sufficient voltage to overcome that of the battery.

Fall in Pressure. When either a pump or a dynamo is running at a constant speed, the pressure, or voltage, produced at the machine is practically constant. But in the case of the water system, the pressure is not the same at the outlet of a branch line a mile away from the power house as it is at the delivery end of the pump, nor is the voltage on a branch circuit at a great distance from the dynamo the same as it is at the terminals of the latter, consequently, the fall in pressure in the water piping is the exact counterpart of

the drop in voltage on the electric circuit due to the resistance of the wires. In the case of the water supply, the friction encountered by the water in passing through the pipes is analogous to the resistance which the electric current must overcome, except that bends in a wire do not impose any greater resistance to the current than the same length of wire when straight, whereas bends in piping greatly add to the friction with a correspondingly greater drop in pressure.

Friction and Resistance. There is, in consequence, almost an exact parallel between the mechanical friction of water passing through a pipe and that of the electric current passing through a wire, as it is commonly said to do. Friction in water piping is inversely proportional to the size of the pipe in proportion to the pressure to which the water is subjected, and is directly proportional to the length of the pipe in exactly the same way that a wire opposes more resistance to the electric current the smaller the wire is, and the amount of resistance also increases with the length of the wire itself. In both cases, the product of this friction, or resistance, is heat; and it results in a drop in pressure, whether mechanical or electrical.

Current and Volume. So far the comparison has been limited entirely to the pressure exerted by the pump on the supply line as compared with the voltage of the generator imposed on the circuit. In a similar way the flow of water from the pipe line may be compared with that of the current in an electrical circuit. Assume, for example, that, in the case of the water-supply system, the pumps generate a pressure of 100 pounds to the square inch. Eliminating from consideration any drop in pressure between the pump and outlet as only tending to confuse the comparison, suppose a half-inch faucet to be opened at a distant part of the system. Then there will flow from the pipe an amount of water proportioned to the size of the outlet times the pressure, or head, back of it. Let us assume that this will be one cubic foot per minute, or, roughly, eight gallons.

In the same way, assume that the generator imposes a pressure of 100 volts on the line and, for purposes of comparison, there is no drop between the generator and the end of the line. So long as there is no outlet open there is pressure on the water in the supply system, but no flow. This is likewise the case with the electric circuit. The voltage is present as long as the armature of the dynamo

is revolving, but there is no flow of current in the circuit. A small fan motor, corresponding to the half-inch faucet, is switched on at a distant part of the circuit. There is then a flow of current of, say one ampere. In this case, the hydraulic analogue reflects exactly the action of the current as compared with the water supply in a pipe. If, instead of opening a small house faucet, we open the valve of a branch main a foot in diameter, there is a correspondingly greater volume of water flowing, but the pressure remains the same. On the other hand, if, instead of a small fan motor, a five-horsepower motor is switched into the circuit, the outflow of current will be equivalent to five horsepower, though the voltage of the circuit will remain the same. (There is, of course, always a voltage drop with every piece of apparatus that the current passes through before completing the circuit by returning to the generator, just as there is a drop in water pressure for every additional length of pipe or open outlet in the system; but, to keep the comparison clear and simple, this is not taken into consideration here.) Thus, in one case, we have one cubic foot of water per minute flowing under a head, or pressure, of 100 pounds per square inch; in the other, a current of one ampere at a voltage of 100; also the fact that the volume of either water or electricity that will flow depends upon the resistance of the outlet. The fan motor is wound to a high resistance, and, consequently, only one ampere of current is required to operate it at its maximum speed. In the same way, the ½-inch outlet will permit only one cubic foot of water to escape per minute. Increasing the size of the outlet in either case increases the flow correspondingly. The simile holds good with the water system up to the point where the outlet becomes too large to permit the pumps to maintain the pressure; but, in the case of the electric generator, the resistance cannot be decreased to zero, since this would result in a short-circuit permitting the entire current output of the dynamo to flow. Unless the dynamo were protected by circuit breakers and fuses, the functions of both of which are explained later, the windings of the machine would be burned out.

Power Comparison. To go back to the simile between water and current flow, it will be noted that in one case there is a flow of one cubic foot per minute at 100 pounds to the square inch, and, in the other, a flow of one ampere of current at 100 volts. This

flow of water represents power just as the flow of electric current does, and it may be utilized in a similar manner. The product of the volume times the pressure would give foot-pounds in the case of the water and watts in the case of the electrical energy, in other words, one ampere times 100 volts, or 100 watts—almost one-seventh of a horsepower.

Circuits. The simile of the water-supply system does not correspond exactly to any type of electric circuit, in that the water does not return to the pump in any case, as the current always must to the generator, to complete the circuit. But it does afford a comparison of the characteristics of both series and multiple circuits, showing to what an extent the illustration of electrical principles may be carried by means of a simple mechanical analogue. For instance, the opening of one outlet after another in a water system reduces the pressure in the entire system, just as the insertion of one piece of apparatus after another in a series electric circuit causes a corresponding drop in voltage for each addition, except, of course, that in case of the series electric circuit it must always be complete, regardless of whether one or a dozen different pieces of apparatus be included in it. In other words, the current must pass through each one of them in turn to complete the circuit. On the other hand, the water system has some of the characteristics of a multiple, or parallel, electric circuit, in that the opening of one outlet does not prevent the use of others, whereas in the series circuit, the breakdown of one piece of apparatus, such as a motor or a lamp, puts all the others out of action by opening the circuit.

The comparison may be carried still further to illustrate other attributes of the electric circuit. For example, if there be a bad break in one of the large mains of the water system, no water will reach smaller outlets beyond the break in the main, the entire volume flowing out of this opening. This corresponds very closely to a ground or short-circuit on an electric circuit. If one of the wires, instead of carrying the current to the motors, permits its supply to return to the generator by a shorter path, due to faulty insulation or a broken wire touching the ground, no useful work will be performed by the current. It will escape and be wasted just as the water is, with this important difference, however, that in the case of the water pumps, the break in the main will be evidenced

only by a marked decrease in the pressure, and the pumps will run to no purpose, whereas the electric generator will still continue to generate its full voltage, and, unless the grounded circuit caused by the break has sufficient resistance, the circuit breaker, or fuses, must operate to protect it.

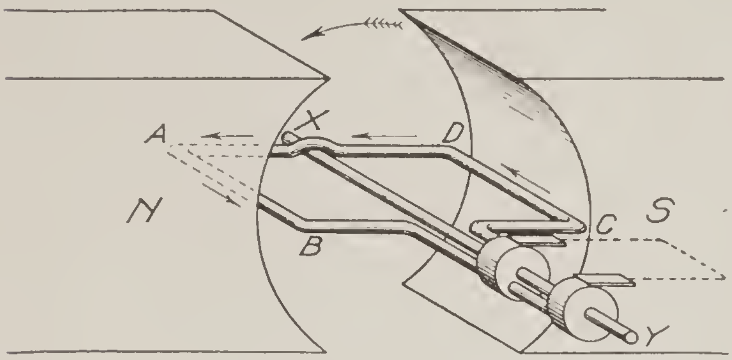


Fig. 17. Elementary Principle of Generator

GENERATOR PRINCIPLES

Classification. All dynamo-electric machines are commercial applications of Faraday's discovery of induced currents in 1831. They are all designed to transform the mechanical energy of a steam engine, a waterfall, a gasoline engine, etc., into the energy of an electric current. Whenever large currents are required—for example, in running street cars; in systems of lighting and heating; in the smelting, welding, and refining of metals; the charging of storage batteries, etc.—they are always produced by dynamo-electric machines.

There are two kinds of generators (1) d.c., or those producing a unidirectional (direct) current, that is, one which always flows in the same direction in the external circuit, and (2) a.c., or those producing an alternating current, that is, one which reverses in direction continuously throughout the entire circuit.

Elementary Dynamo. Whenever lines of magnetic flux are cut by a conductor, for example, by a wire passing through them, an e.m.f. (electromotive force) is produced in the conductor, and the strength of this e.m.f. is entirely dependent upon the speed at which the conductor passes through the magnetic field. If, at the time that this is done, the ends of the wire are brought together to form a circuit, a current will be induced in the conductor. The simplest form of generator would consist of a single loop of wire $ABCD$ arranged to rotate in a magnetic field, as shown by Fig. 17. Having its plane parallel to the direction of the magnetic flux, the loop, if it be rotated to the left as shown, will have an e.m.f. induced in it that will tend to cause a current to flow in the direction shown by the arrows. The e.m.f.'s induced in AB and CD for the position shown will have their maximum values since the wires are then cut-

ting the magnetic flux at right angles and are consequently cutting more lines of force per second than in any other part of the revolution. Note that as CD moves up, AB moves down (and vice versa) across the magnetic flux so that the induced currents in all parts of the loop at any instant are flowing in one direction. The value of this e.m.f. depends upon the speed, and as the loop approaches the 90-degree, or vertical, position, the e.m.f. decreases because the rate of cutting is diminishing, until when the loop is vertical both the cutting of the magnetic flux and the generated e.m.f. are at zero. If the rotation is continued, the rate again gradually increases, until at 180 degrees it is once more a maximum. The cutting, however, in the two quadrants following the 90-degree position has been in the opposite direction to that occurring in the first quadrant, so that the direction

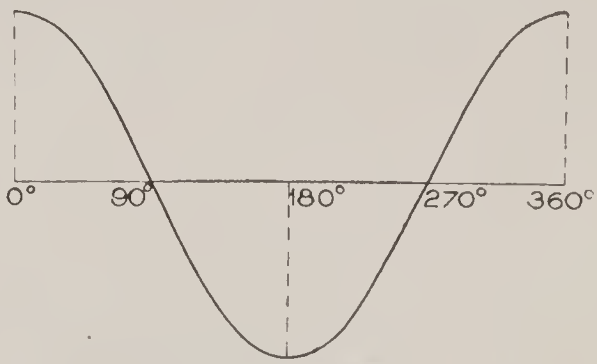


Fig. 18. Dynamo E. M. F. Curve

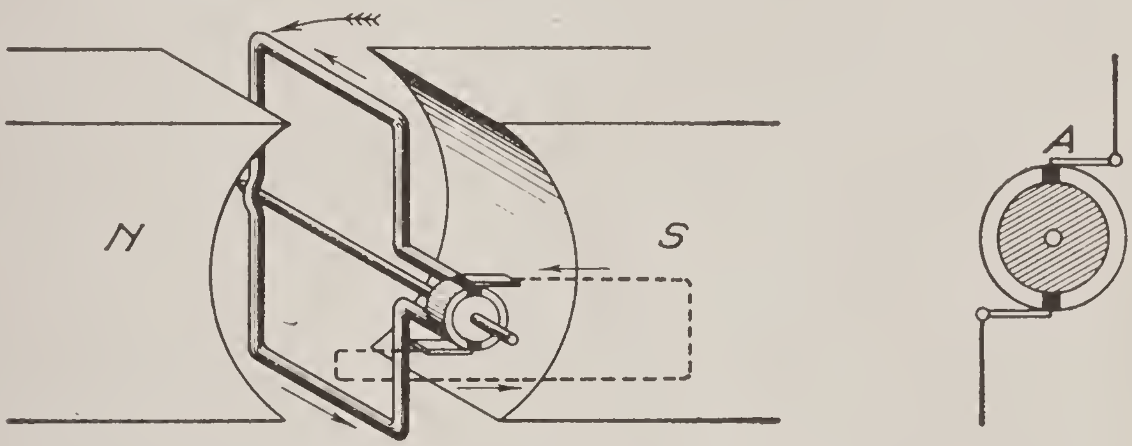


Fig. 19. Simple Form of Generator Showing Arrangement of Brushes in Contact with Commutator

of the e.m.f. generated is reversed. Plotting this through an entire rotation gives the curve shown in Fig. 18. Such an e.m.f. is termed alternating because of its reversal from positive to negative values, first in one direction and then in the other, through the circuit. It cannot be utilized for charging a storage battery, and hence it is not employed in connection with starting and lighting dynamos and motors. To convert an alternating current into a direct or continuous current, a commutator must be added.

Commutators. Fig. 19 illustrates a commutator in its simplest form. It may be imagined as consisting of a small brass tube which has been sawed in two longitudinally, the halves being mounted

on a wooden rod. The wood and the two cuts in the tube insulate the halves from each other. Each one of these halves is connected to one terminal of the loop, as shown in the illustration, Fig. 20. Against this commutator, Fig. 19, two brushes bear at opposite points and lead the current due to the generated e.m.f. to the external circuit. If these brushes are so set that each half of the split tube moves out of contact with one brush and into contact with another at the instant when the loop is passing through the positions where the rate of cutting is minimum (as indicated in the enlarged end view of the commutator shown at *A*), a unidirectional current will be produced, but it will be of the pulsating character as indicated by the curve for one cycle shown in Fig. 21.

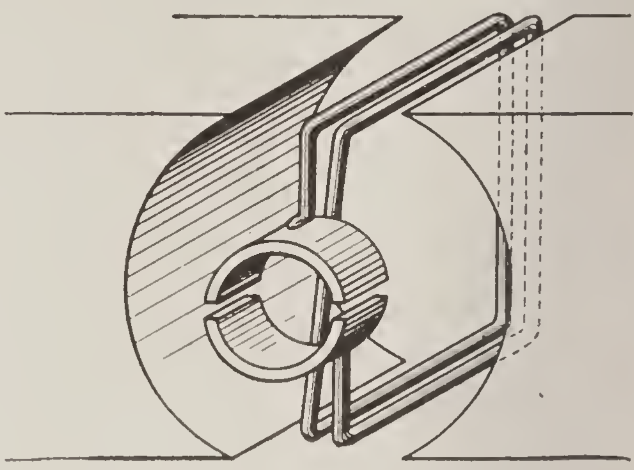


Fig. 20. Commutator with Double Turn

This would also be the case, if instead of the single loop, a coil wound on an iron ring be substituted, as in Fig. 22, the only effect of this being to increase the e.m.f. by increasing the number of times the electrical circuit cuts the magnetic flux. Now assume that two coils are connected to the commutator bars, instead of the single loop, shown in Fig. 22. This arrangement will give the simple device shown in Fig. 23, called an armature. The two coils are

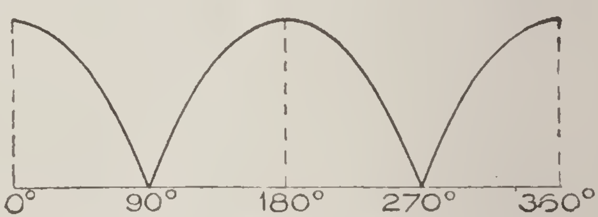


Fig. 21. E. M. F. Curve with Commutator

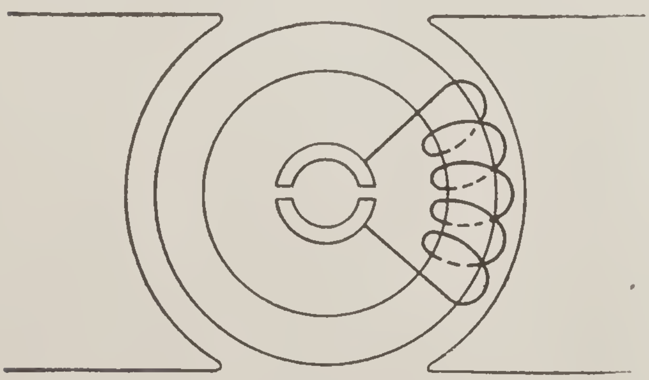


Fig. 22. Armature with Single Coil

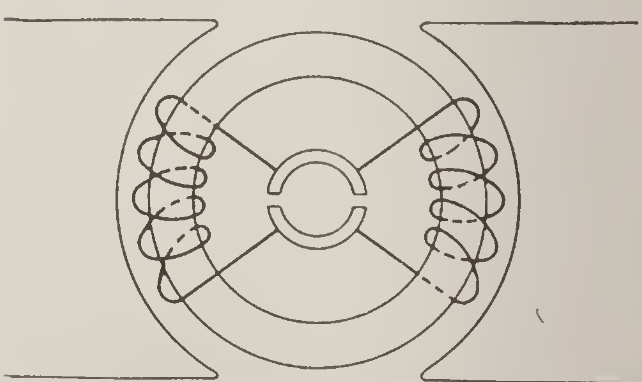


Fig. 23. Two-Coil Armature

in parallel and while the voltage generated by revolving this winding with two coils is no greater than with one coil, the current-carrying capacity of the winding is doubled. The current generated by

this form of armature would still have the disadvantage, however, of being pulsating. As in the case of the automobile motor, the number of cylinders must be increased to make the power output a continuous unbroken line, so armature coils and their corresponding commutator brushes must be added that one set may come into action before the other "goes dead". By placing an extra pair of coils on the armature, at right angles to the first, as shown in Fig. 24, one set will be in the position of maximum activity when the other is at the point of least action. While this armature would produce a continuous current, it would not be steady, having four pulsations per revolution, and it is consequently necessary to increase the number of coils and commutator segments still further to generate a steady, continuous current. This is what is done in practice.

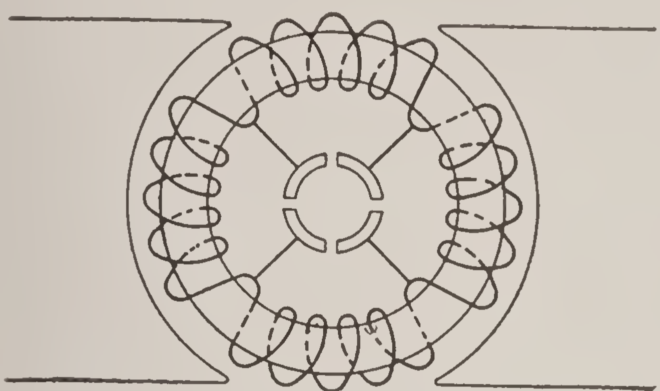


Fig. 24. Four-Coil Armature

A commutator consists of a number of copper bars or segments, equal to the number of sections in the armature. These bars are separated by sheets of insulating material, usually mica, and are

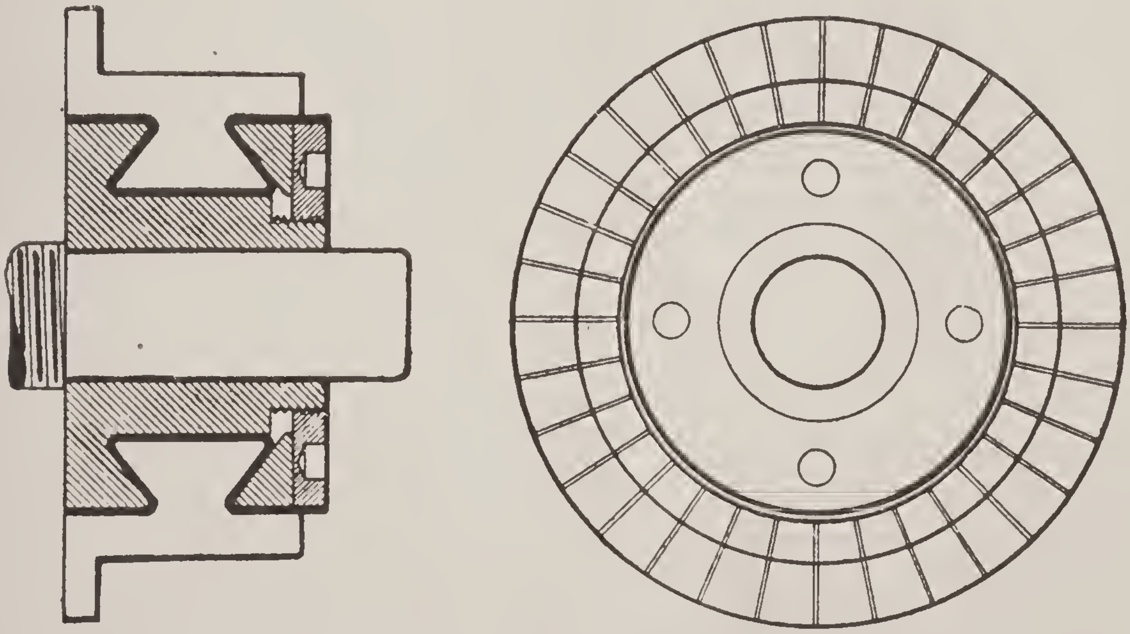


Fig. 25. Sectional and End Views of a Commutator
Courtesy of Horseless Age

firmly held together by a clamping device consisting of a metal sleeve with a head having its inner side undercut at an angle, a washer similar in shape to the head of the sleeve, and a nut that

screws over the end of the sleeve, as shown in the left-hand or sectional view of Fig. 25. The sleeve is surrounded by a bushing of insulating material, and washers of the same material are placed between the assembly of commutator bars and the two clamping heads. Each bar is then completely insulated from every other bar and from the clamping sleeve. Commutators are also made by pressing the entire assembly of copper segments together, or molding them, in insulating material (Bakelite), which thus forms the hub or mounting of the commutator as well as the insulating material between the segments. After assembling, the commutator is turned down in a lathe to a true-running cylinder and then sand-papered on its outer cylindrical surface to present a smooth bearing surface for the brushes. At the inner end of the commutator which is closest to the armature windings, the commutator bars are provided with lugs as shown in the sectional view; these lugs are slotted and the armature leads are soldered to them. At the right, Fig. 25, is shown an end view of the same commutator.

From the repair man's point of view, the commutator is the most important part of the generator or the motor, since it is one of the first with whose shortcomings he makes acquaintance. Practically all lighting and starting motors now have their armature shafts mounted on annular ball bearings, so that the commutator and the brushes are the only parts that are subject to wear. If the time devoted in the garage to the maintenance of automobile electric systems were to be divided according to the units demanding attention, the battery would naturally come first, brushes and commutators next, then switches, regulating instruments, connections, and wiring, about in the order named. After all of these come, of course, burnt-out armatures or other internal derangements which necessitate returning the units to the manufacturer; but troubles of this nature are quite rare. While this list gives the order of precedence, it has no bearing on the relative importance of the troubles; with respect to the total time taken by each, the battery is responsible for not far from 90 per cent, the commutator for about 5 per cent, all other causes comprising the remaining 5 per cent.

Armature Windings. In the simple illustrations given to show the method of generating e.m.f. in the armature and leading

the current to the external circuit, what is known as the ring type of winding is shown. This is inefficient because half the length of the conductor—the portion inside the ring—does not cut any lines of force and hence does not aid in generating the current. The design, moreover, does not lend itself to compactness, so that it would not be adapted to automobile work even if there were no objection to it on the score of inefficiency. A slotted type of armature core is very generally employed for the small generators and starting motors used on automobiles and the wire is either wound directly in the slots, or is "form wound", that is, the wire is placed on a wooden form shaped to correspond to the position the coil will take when in place on the armature. After winding the necessary length of conductor on this foundation, the wire is taped together, and varnished or impregnated with an insulating compound, and baked.

Owing to its high magnetic permeability, iron is universally employed for the core of the armature, since the function of the core is to carry the magnetic flux across from pole to pole of the field magnets, as well as to form a foundation for the coils. However, when a mass of iron is rotated in the field of a magnet what are known as "eddy currents" are set up in the metal itself, and these prevent the inner parts of the mass from becoming magnetized as rapidly as the outer and also cause the interior to retain its magnetism longer. As the efficiency of the generator depends upon the rapidity with which the sections of the armature become magnetized and demagnetized as they revolve, the lag due to these eddy currents is a detriment. To reduce this effect to the minimum, the armature cores are always laminated, that is, built up of thin disks of very soft iron or mild steel, these disks having the necessary slots punched in them to accommodate the windings when assembled on the shaft. The disks are insulated from one another either by varnishing them or by inserting paper disks between them. They are assembled on the shaft and are put together under considerable pressure, various means being employed to hold them in place. These disks arè so thin that hundreds of them are required to make an armature core only a few inches long, and when pressed together in place they are to all intents and purposes a solid mass.

Armature winding, however, is something that is entirely beyond the province of either the car owner or the repair man, no

matter how well equipped a shop he has. It is a job for the expert in that particular line, and on the rare occasions when an armature does go wrong, it should always be returned to the manufacturer, if possible, if not, to a shop making a speciality of such work.

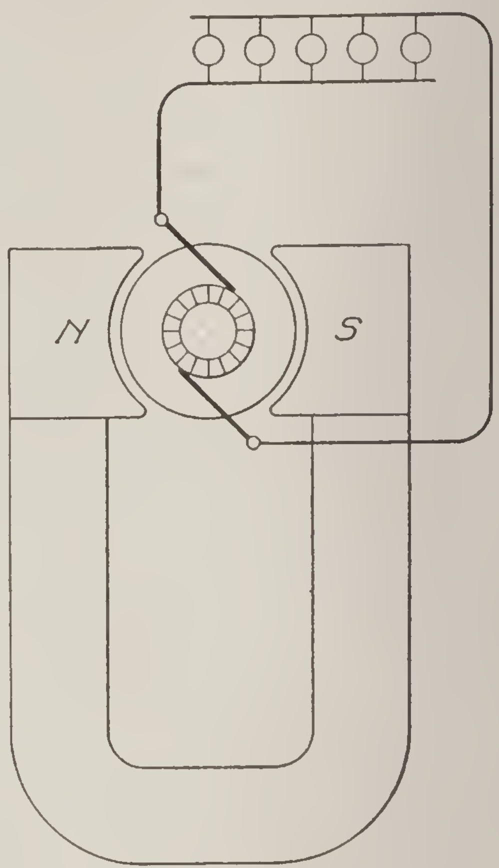


Fig. 26. Diagram of Magneto

Field Magnets. In the foregoing explanation of the generation of an e.m.f. in a conductor when rotated in a magnetic field and the leading out of the current through a commutator, the presence of the field has been assumed and nothing has been said regarding the method of providing it. The term field is applied interchangeably to the magnetic flux between the pole faces of the field magnets and to the magnets themselves, but it is more generally understood to refer to the latter directly and to the former by inference. There are various methods of maintaining the flux, usually described as "field magnet excitation", but only two of them are applicable to the electric generators employed on the automobile.

Permanent Field Used in Magneto. The simplest of these, and the first to be designed, employed permanent magnets, from which such a generator takes its name, *magneto*. Fig. 26 is a diagrammatic representation of an early form of the magneto-generator. Since magnetism cannot be maintained permanently at the high flux-density or strength which can be produced by an exciting coil fed by a current, this method is only employed in very small generators, as its bulk for large powers would be excessive. Its great advantage is its simplicity and constancy. The magneto-generator shown in Fig. 26, however, is designed to produce a continuous current, and is not the type in general use on the automobile today.

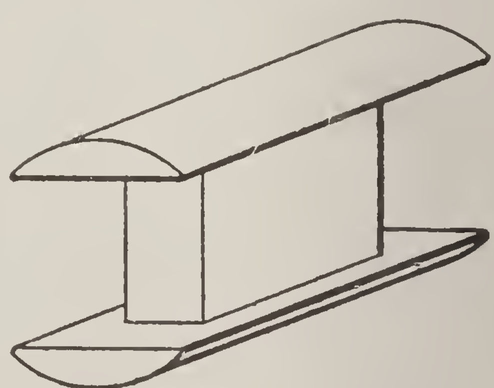


Fig. 27. Sketch Showing Shape of Armature Core
Courtesy of Horseless Age

The type usually installed is made with a two-pole armature, as shown by Fig. 27. This figure illustrates the core known as a "shuttle" type because the wire is wound around the center of the core in much the same manner as thread is put on a shuttle. These cores are laminated as already described, in all well-built magnetos. The space on the core is filled with a single coil of comparatively coarse wire on the majority of magnetos, which generate a low voltage current that is subsequently stepped up through an outside transformer. In some instances, in what may be termed the true high-tension type of magneto, there is a second winding of fine wire on the core so that the magneto generates a current

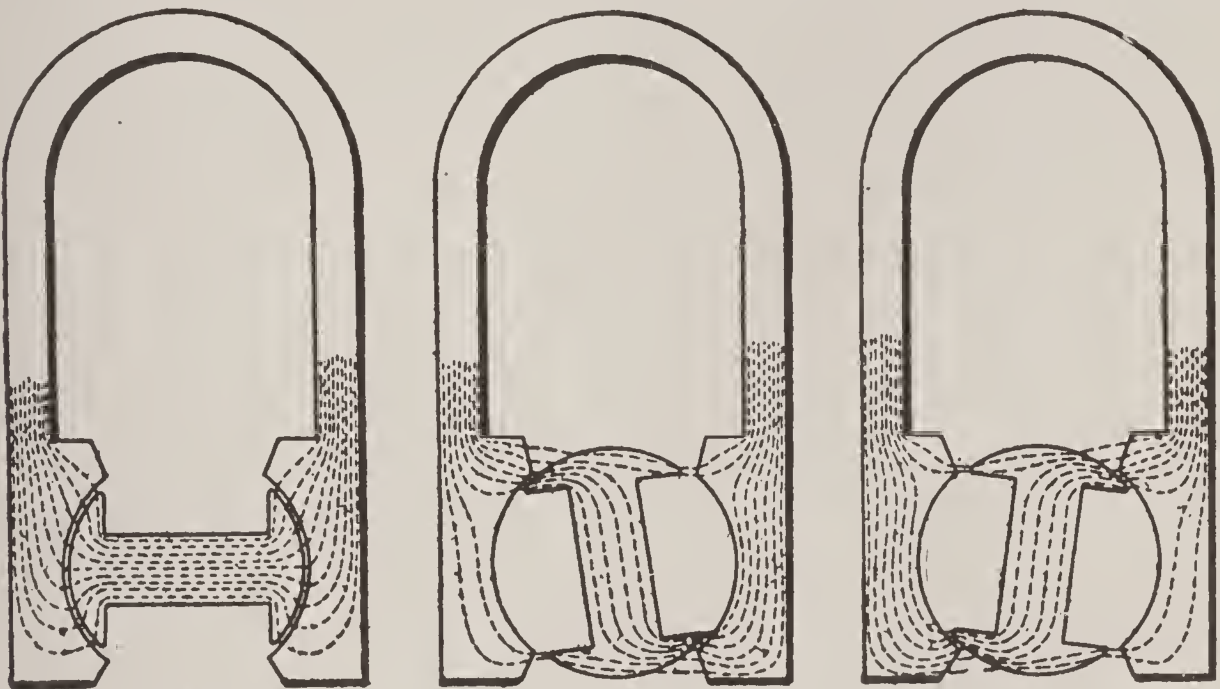


Fig. 28. Diagrams Showing Distribution of Magnetic Flux for Various Positions
Courtesy of Horseless Age

and steps it up without the aid of any outside devices. In either case, one end of the winding is "grounded on the core", that is, connected to it electrically, so that the core and other metal parts of the machine form one side of the circuit, while the other end is connected to a stud against which a spring-controlled carbon brush bears, to collect the current. Detailed descriptions of various types of magnetos are given later so that nothing further concerning the construction need be added here.

Principle of Operation of Magneto. Under "Generator Principles", the principle of the operation of the magneto has already been explained, the method by which the rotation of the conductors in the magnetic field generates an e.m.f. and a current is induced

in them. But as the actual operation of the magneto as designed for ignition purposes is radically different from any other form of generator, it is given here. If unrestricted, the armature of the magneto will always assume the position shown at *A*, Fig. 28, and considerable effort will be required to turn it from this position as the magnetic flux through the armature is then a maximum. When the armature is rotated a little over 90 degrees from this horizontal position so that the armature poles leave the field poles, as at *B* in the same figure, the flux decreases, and when in a vertical position no lines of force pass through it. At this point, the direction

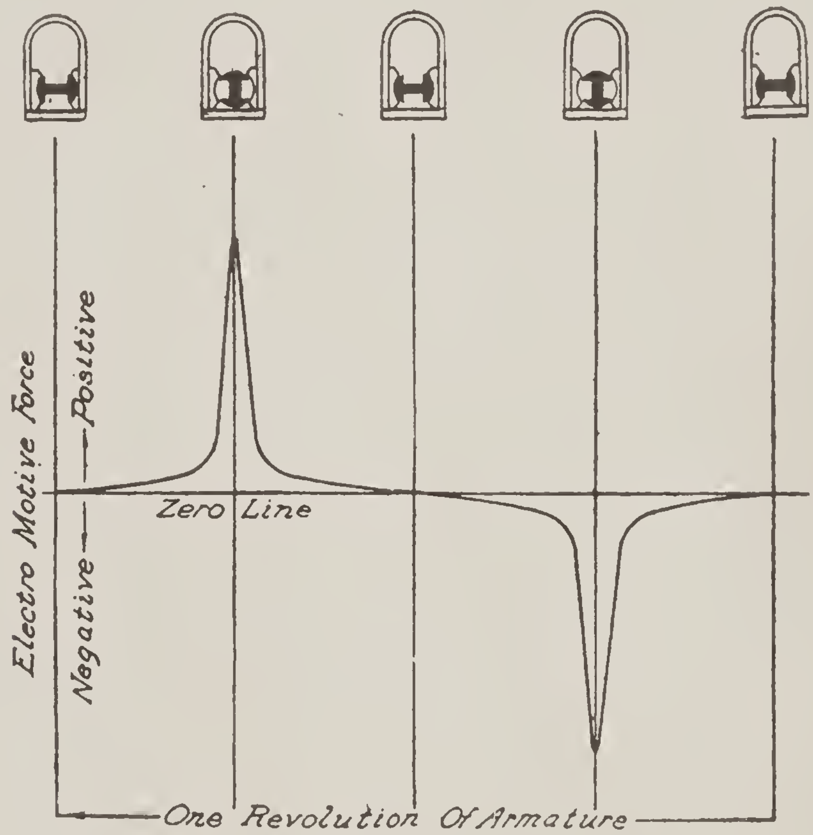


Fig. 29. Curve of Primary E. M. F. in Magneto on Open Circuit
Courtesy of Horseless Age

of the magnetic flux through the armature core reverses. Having a two-pole armature, the magneto produces an alternating current of two complete cycles per revolution, as shown by the curve, Fig. 29, which illustrates the electromotive force generated at the different positions in the rotation of the armature. The similarity between this curve and the one generated by the elementary dynamo, Fig. 17, will be noted. With the armature in the horizontal position there is a dead point, the e.m.f. curve only starting as the pole pieces of the armature begin to cut the edges of the field magnet poles. It then rises very sharply to a peak, and as sharply drops

away to zero again, thus completing one cycle, which is then repeated in the opposite direction. As the present discussion comprises only an introduction to elementary principles and theories, further details of construction and operation of the magneto are given later in the section on "Ignition".

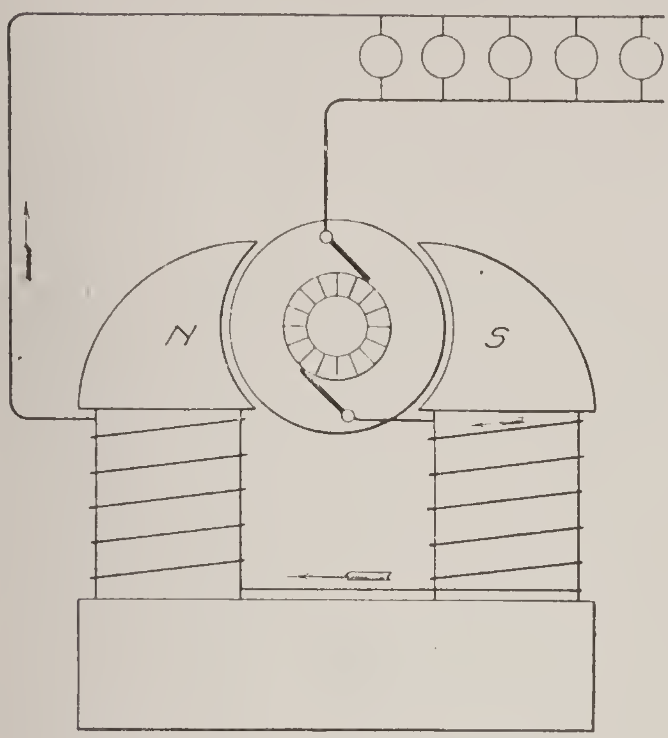


Fig. 30. Diagram Showing Series Generator

Self-Excited Fields. In a machine of the magneto type, the only method of varying the current output is to vary the speed of the armature, and it is therefore not well adapted to the majority of uses for which a generator is employed. Consequently, other methods of exciting the fields have been developed, which may be roughly divided into two classes: *first,* those separately excited, in which current from an independent source is supplied to the field windings. This is now practically restricted to large alternating-current generators and so need not be considered further here. *Second,* self-excited fields, which are now characteristic of all continuous current generators. In this method all or a part of the current induced in the armature windings is passed through the field coils, the amount depending on the type of generator.

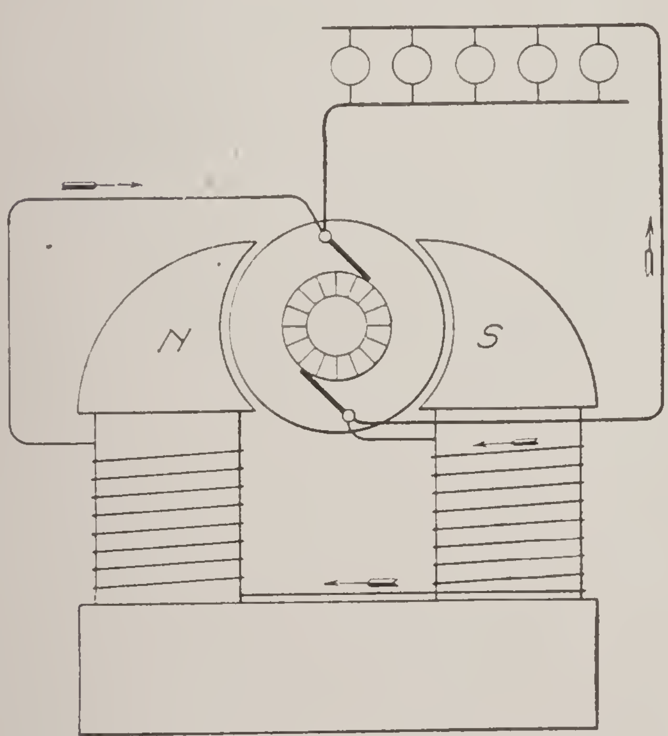


Fig. 31. Diagram Showing Shunt-Wound Generator

Series Generator. Where the entire current output is utilized for this purpose, the dynamo is of the series type, and a reference to the section on "Circuits", in connection with the illustration, Fig. 30, will make this plain. There is but a single circuit on such a dynamo and while it

has the advantage of simplicity, it does not generate a current until a fairly high speed is reached, or unless the resistance in the external circuit is below a certain limit. It is also likely to have its polarity reversed so that it is not fitted for charging storage batteries. As the only series generators put into commercial use have been for supplying arc lamps in series for street lighting, they need not be considered further.

Shunt-Wound Generator. By winding the generator with two circuits instead of one and giving that of the fields a relatively high resistance as compared with the outside circuit on which the generator is to work, a machine that is self-regulating within certain limits is produced. As shown by Fig. 31, the main circuit of the generator is that through the armature with which the field winding is in shunt. The current accordingly divides inversely as the resistance and only a small part of it flows through the field coils, while the main output of the generator flows through the external circuit to light the lamps, to charge a battery, or the like, the resistance of this external circuit being much less than that of the fields. But in this type, as well as in the simple series form, the e.m.f. generated varies more or less with the load, and as the latter is constantly changing, it is necessary to provide some means of varying the e.m.f. generated to suit the load, in other words, to make the generator self-regulating. Of the several available methods of doing this, the only one applicable to the small direct-current generators used in automobile lighting and starting systems, is that of varying the magnetic flux through the armature.

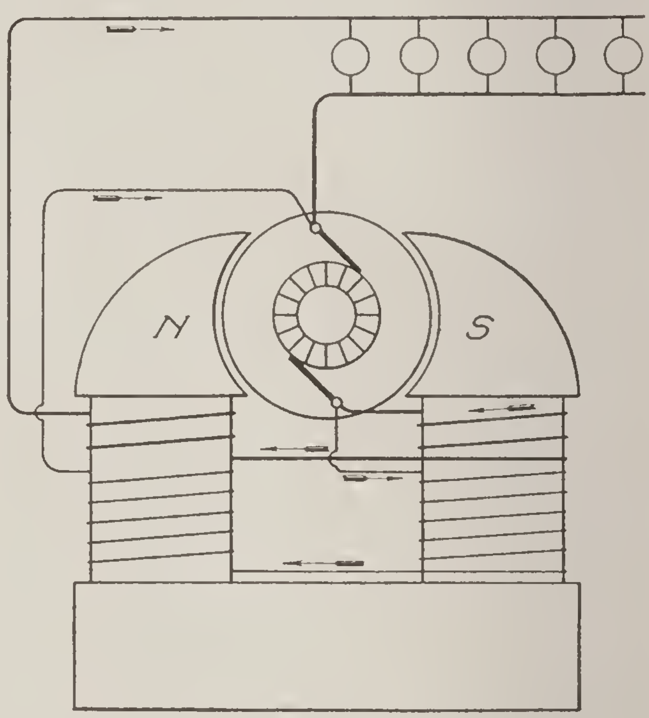


Fig. 32. Diagram Showing Compound-Wound Generator

Compound-Wound Generator. There are also several methods of effecting this variation of the magnetic flux, but the most advantageous and consequently the most generally used, is to vary the amount of current in the energizing coils on the field magnets.

By adding to the shunt winding a few turns of heavy wire in series with the armature so that all the current passes through them, the magnetic flux may be made to increase with the load as it is directly affected by the current demanded by the latter. This combination of the shunt and series is termed a compound winding, and the usual method of affecting it is shown by Fig. 32. Such a machine

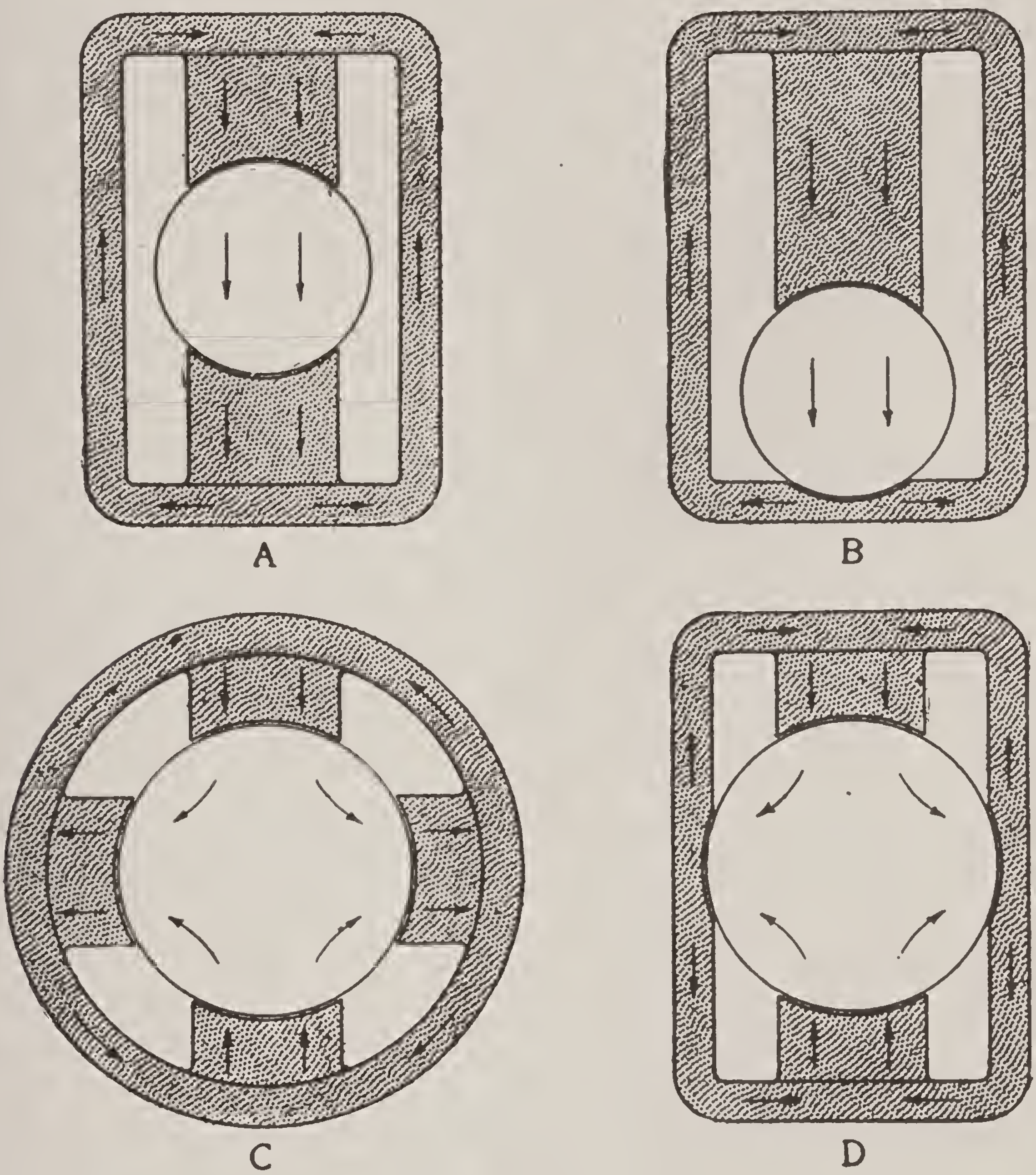


Fig. 33. Forms of Field Frames

is called a compound generator, and is the type almost universally used for lighting and for charging the storage batteries of automobiles. In view of the great range of speed variation of the automobile motor, this compound wiring is sometimes reversed so as to act against the shunt instead of with it, in order to prevent an excessive amount of flux and a current that would be dangerous to the windings themselves due to a very high speed. The compound

winding then opposes the shunt-winding and is termed a *bucking-coil* or winding. This is referred to later in connection with the discussion of methods of regulating the generator on the automobile.

Forms of Field Magnets. For greater simplicity, all of the illustrations shown in connection with the explanation of the various types of generators are of the old bipolar type in a form long since obsolete. The field frame, as it is designated may, however, take a number of different forms depending entirely upon the designer's conception of what best meets the requirements of ample power in the minimum of space and with the minimum weight. Fig. 33 shows some typical forms of field frames in general use on automobile generators, and it will be noted that in addition to providing a magnetic circuit the field frame also serves to enclose the windings. These are known as "ironclad" types from the fact that all parts are thoroughly enclosed and protected. The arrows in each case indicate the paths of the magnetic circuits, the number of the circuits varying with the number of pole pieces. The form at *A* has two opposed poles, each of which is designed to carry an exciting coil or winding. This is a bipolar machine. Field frame *B* is also of the bipolar type but only one pole carries an exciting winding, the other being known as a consequent pole. In both of these field frames, it will be noted that the magnetic circuits are long, which adds to the magnetic reluctance and tends to decrease the efficiency. To overcome this, multipolar types of field frames are very generally employed. One of these, with two wound or salient poles and two consequent poles, is shown at *D*, the extra poles making four short instead of two long magnetic circuits. *C* is a multipolar type with four salient poles.

Brushes. Brushes serve to conduct the current generated by the armature to the outer circuit and to the field coils in order that the excitation of the latter may correspond with the demand upon the generator. The brushes originally employed were strips of copper which bore on the commutator; as generators increased in size these brushes were built up of thin laminations of copper. Plain copper brushes in any form, however, cause an excessive amount of sparking which is ruinous to the smooth surface and true running of a commutator. Built-up copper gauze brushes were then adopted, and they were fitted to bear against the com-

mutator. Though an improvement, these did not meet all the requirements and were in turn superseded by carbon brushes, which are now practically universal. The carbon brushes usually bear directly against the face of the commutator, either through a blunt, squared end, or one that is slightly beveled. The brush holders are generally bronze castings attached directly to the field-frame extensions; in them are placed small helical springs under compression, which serve to press the brush against the commutator. Ordinarily, the brushes are composed of a uniformly smooth and homogeneous compound of carbon that soon acquires a glazed surface at its bearing end and wears indefinitely without requiring any attention, but at times a gritty brush will be found. Such a brush scratches the commutator surface, wears unevenly, and is generally a source of trouble.

Badly worn commutators frequently result from the use of improper brushes, or too heavy a spring pressure—also from too light a spring pressure. The manufacturer has found out by experiment and study just what character of brush is best adapted to his particular generator or starting motor and also the exact amount of spring pressure that is necessary to insure the best results. Consequently, much trouble will be avoided if brushes are replaced only with those supplied by the manufacturer of that particular machine, in connection with the brush springs that were designed for it. There are electrical as well as mechanical reasons for this, since both the resistance and current-carrying capacity of carbon brushes vary. This has been taken into consideration by the manufacturer who has provided a brush especially adapted to his machine.

ELECTRIC MOTOR PRINCIPLES

Theory of Operation. A machine that is designed to convert mechanical into electrical energy or the reverse, is known as a *dynamo-electric machine*. When its armature is rotated by an external source of power, such as a steam engine, hydraulic turbine, or gasoline engine, it is a *generator*. By sending a current through it from another generator or a battery it converts electrical into mechanical energy and is a *motor*. It is evident, then, that a generator and a motor are fundamentally one and the same thing, and that by a reversal of the conditions one unit may be made to

serve both purposes. It will naturally depend upon how closely these purposes approach each other so far as their operating conditions are concerned, whether it will be practical to employ the same machine for both. In practice, operating conditions rarely approximate and so before the advent of the single-unit starting-and-lighting system on automobiles the use of the same machine for both generating current and converting it into mechanical energy was practically unknown. Space considerations were the chief factor which led to the development of the single system, as the demands on the machine for charging the battery and starting the engine are radically different.

How Rotation Is Produced. The operation of an electric motor will be clear if the essentials of a dynamo-electric machine and their relations are kept in mind. There is, first, the magnetic field and its poles—two or any multiple thereof, though for space reasons more than four poles are seldom used in starting motors; then the armature, which must also have an even number of poles corresponding to the number of segments in the commutator. Each separate coil in the armature winding magnetizes that section of the armature core on which it is wound, when the current passes through it, as its terminals, connected to different segments on the commutator, come under the brushes. In an electric motor having either two or four field poles, and eight, twelve, or sixteen armature poles, it is apparent that every few degrees in the revolution of the armature an oppositely disposed set of its poles is either just approaching or just leaving the magnetic field of two of the field poles. Bearing in mind that like poles repel one another and that unlike poles attract, and that the polarity of both the fields and the armature coils is constantly being alternated by the commutator, we see that each section of the armature is constantly being attracted toward and repelled from the field poles.

The fundamental law just stated can be easily illustrated by taking two common horseshoe magnets, such as can be bought for a few cents. Placing their north and south poles together it will be found that they have no attraction for each other and cannot be made to adhere in this relation. If they had sufficient force they would actually move apart when placed on a smooth surface in this position. But if one of the magnets is turned around

so as to bring the north and south poles of the two opposite each other, the magnets will be immediately attracted and will hold together to the full extent of their force.

What may be called one cycle of the operation of an electric motor may be described as follows: the motor turns clockwise; it is of the bipolar type, that is, it has two field poles; and there are eight coils on the armature. At the moment assumed, the left field pole is the north, and the right south; consequently, the section of the armature just entering the field is of opposite polarity, presenting a south pole to the north pole of the field and a north pole to the south pole of the latter. The armature is therefore strongly attracted. This attraction is maintained by the current in the windings continuing in the same direction until the magnetic attraction reaches a maximum, at which point the stationary and moving poles are practically opposite each other. Unless a change occurred just at that point the armature would be held stationary and could be turned from it only by the expenditure of considerable force, that is, assuming that the field did not lose its exciting current. (This may be observed on a small scale by attempting to revolve the armature of a magneto by turning its shaft by hand.) But either at that point, or just before it is reached, the revolution of the armature brings a different set of commutator bars under the brushes and the direction of the current is reversed in that particular winding and with it the polarity of the armature poles. Instead of being mutually attracted the armature and field poles become mutually repellent. In brief, the armature is first pulled and then pushed around in the same direction by reason of the force exerted both by the field magnets and by its own magnets. The passing of one section of the armature through this change as it enters and leaves the zone of influence of a pair of pole pieces may be said to constitute a cycle of its operation, by analogy with alternating-current generation. The cycles are repeated as many times per revolution as there are coils on the armature and the number of coils miltiplied by the speed will give the number of changes per minute. For example, in a motor assumed to have eight armature coils, as in the present instance, there would be, at a speed of 1,000 r.p.m., 16,000 changes per minute, which makes clear the reason for the very smooth pull or torque that an electric motor exerts.

Counter E.M.F. Though being rotated by means of current obtained from an external source of power, it is apparent that the motor armature in revolving its coils in the magnetic field is fulfilling the conditions previously mentioned as necessary for the generation of an e.m.f. Experiment shows that the voltage and current thus generated are in an opposite direction to that which is operating the motor. It is accordingly termed a counter e.m.f. as it opposes the operating current. This, together with the fact that the resistance of copper increases with its temperature and that the armature becomes warmer as it runs, explains why the resistance of a motor is so much greater when it is running than when standing idle. The counter e.m.f. approaches in value that of the line e.m.f., or voltage at which current is being supplied to the motor. It can, of course, never quite equal the latter for in that case no current would flow. The two opposing e.m.f.'s would equalize each other; there would be no difference of potential.

Types of Motors. Being the counterparts of electric generators, electric motors differ in type according to their windings in the same manner as already explained for generators. The plain series-wound motor is nothing more or less than the simple series-wound generator to which reference has already been made; the shunt and compound motors likewise correspond to the shunt and compound generators. But while the series-wound generator was of extremely limited application and has long since become obsolete, the series-wound motor possesses certain characteristics which make it very generally used. It is practically the only type employed for starting service on the automobile, and it is also in almost universal use for railway service. The reasons for this are its very heavy starting torque which increases as the speed of the motor decreases, the quick drop in the current required as the motor attains speed, and its liberal overload capacity. It is essentially a variable speed motor, and, just as the plain series-wound generator delivers a current varying with the speed at which it is driven, so the speed of the motor changes in proportion to the load. These are characteristics which make it valuable for use both as a starting motor for the gasoline engine, and for a driving motor on the electric automobile, though in the latter case it is seldom a simple series-wound type. As its speed is inversely proportional to the load, however, it tends to race when

the load is light; in other words, it will "run away" if the load is suddenly removed, as in declutching from the automobile engine after starting the latter, unless the current is instantly shut off or very much reduced. This is provided for, as will be explained in detail later in connection with the various systems.

Shunt motors and compound-wound motors are the same as their counterparts, the generators of the same types, but as they are not used in this connection, no further reference need be made to them here.

Dynamotors. As the term suggests, this is a combination of the generator or dynamo and the electric motor, and it is a hybrid

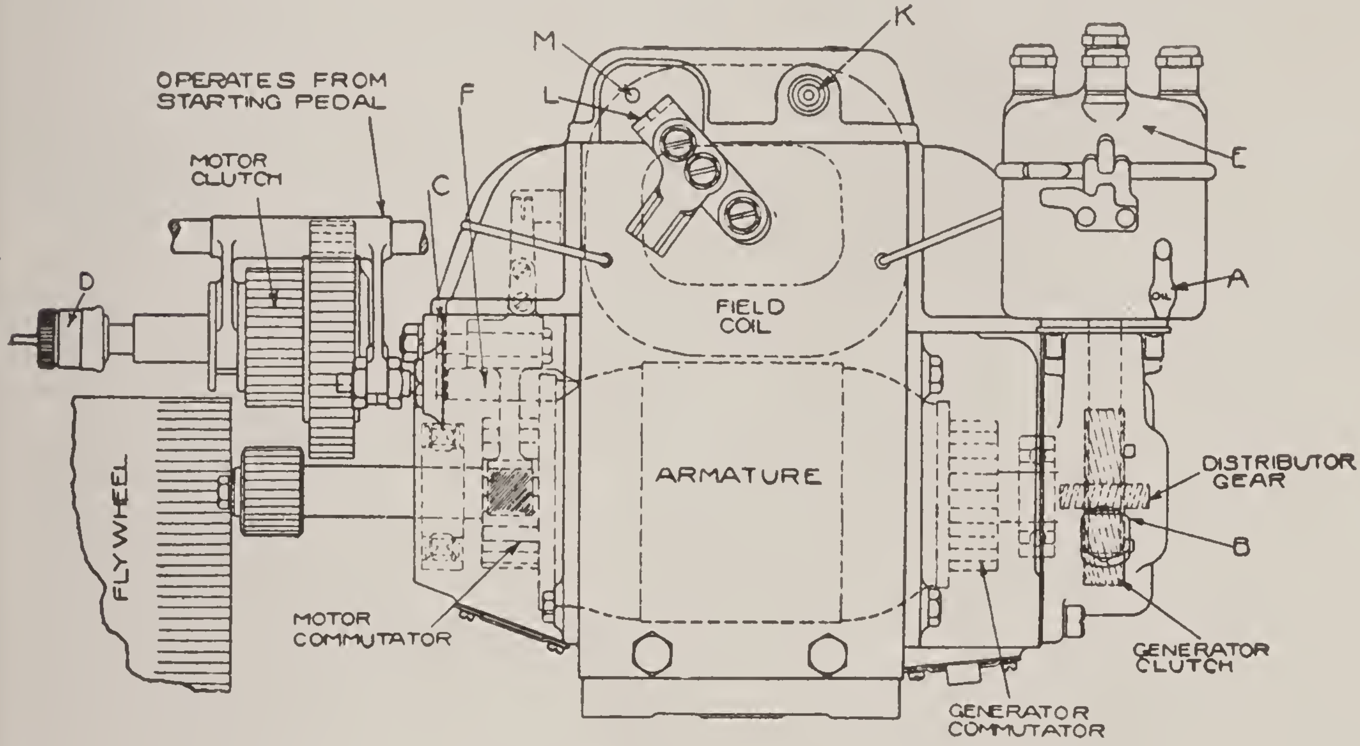


Fig. 34. Dynamotor (Motor-Generator) of the Delco System

for which the automobile starting system has been responsible. It is frequently mistermed a "motor-generator" and while its assumption of the two rôles may justify the name, the use of the term is misleading as it becomes confused with the motor-generators employed for converting alternating into direct current. The latter consist of an a-c. motor on one end of a shaft and a d-c. generator on the other end of the same shaft. The two units are distinct except for their connection, whereas a dynamotor is a single unit comprising both generator and motor, and it can perform only one of these functions at one time. A motor-generator, such as is used in garages for transforming alternating into direct current for charging storage batteries, must carry on both functions at

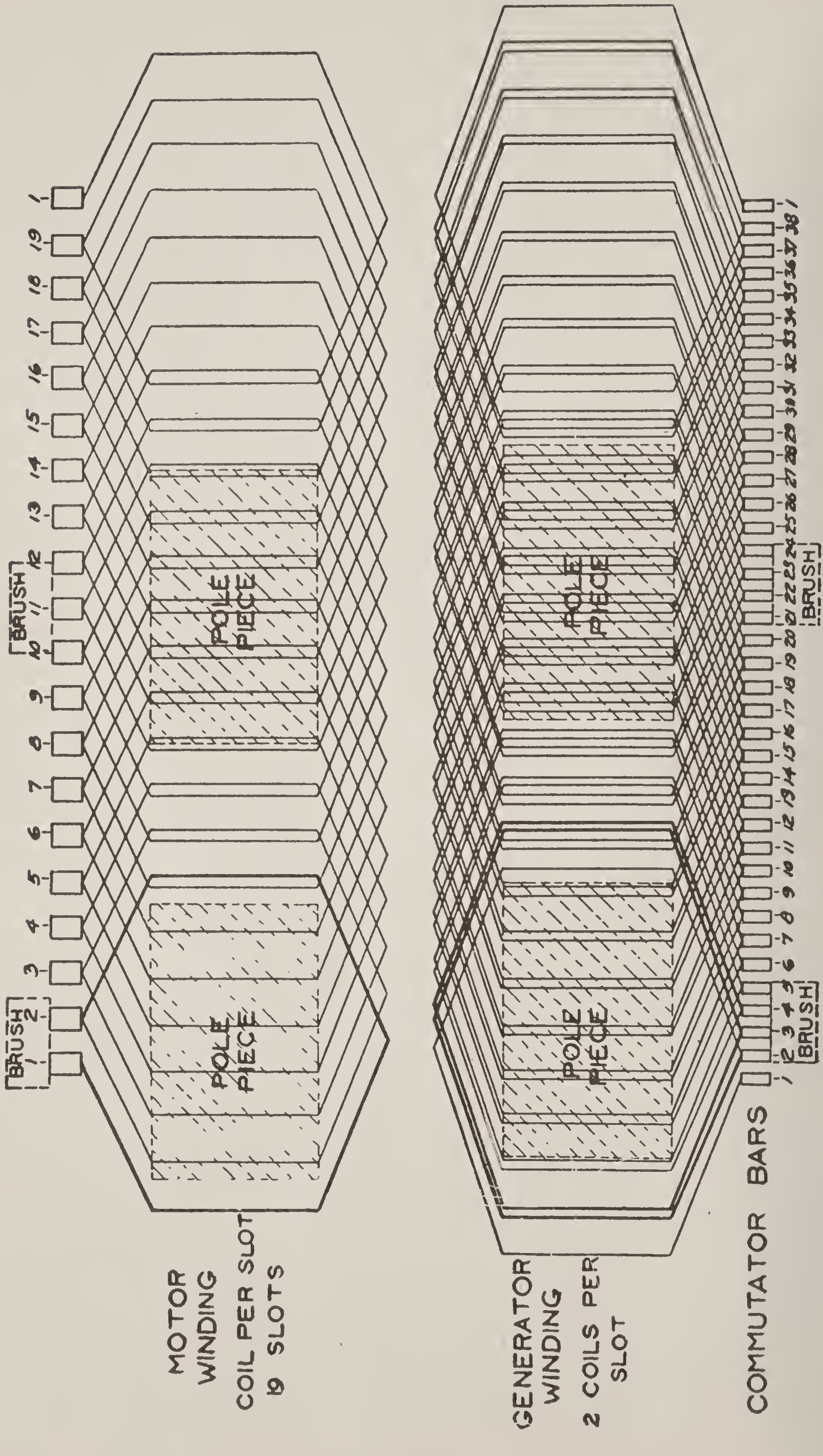


Fig. 35. Windings of Delco Dynamotor

the same time in order to operate. That is, the a-c. motor must run as a motor in order to drive the d-c. generator and cause it to generate a direct current. Hence, the term motor-generator as applied to the single-unit type of electric starting system for an automobile is not in accordance with the accepted meaning of the words and is likely to be confusing.

A typical example of the dynamotor is to be found in the Delco single-unit system, illustrated in Fig. 34. This is really the windings of two radically different machines, a shunt-wound generator and a series-wound motor, placed on the same armature core and field poles. As will be noted, the terminals of the two sets of windings on the armature are brought out in different directions and two commutators are employed, that at the right-hand end being for the generator windings, and that at the left for the motor. The method of winding the armature is illustrated by Fig. 35, which shows the generator and motor windings projected on a plane. In the preceding illustration the detail at the left shows the gearing and starting connection for coupling the starting motor with the flywheel of the engine, the one at the right an ignition distributor for the high-tension current. Both of these are later referred to at greater length.

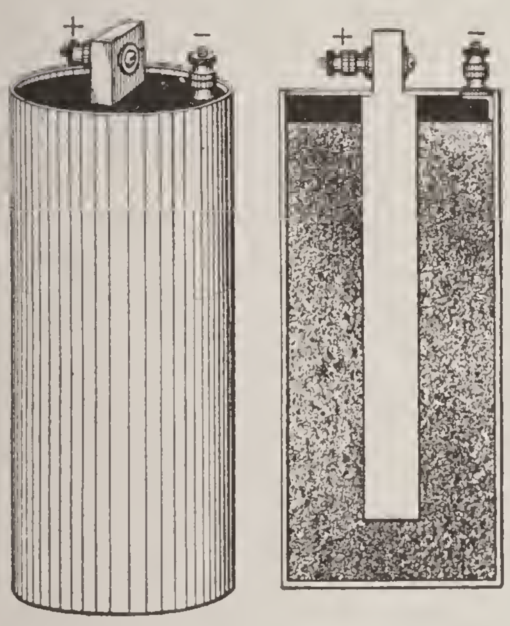


Fig. 36. Typical Dry Battery

Batteries. The only other method known for generating a continuous, direct current is by means of chemical reactions in what are known as primary cells. With the exception of the so-called *dry cell*, a description of these and their workings could be of only historic interest and is accordingly omitted here. As no chemical reaction could take place in perfectly dry substances this part of the name is used simply to distinguish such cells from those using a liquid solution. The dry cell is a zinc-carbon couple, Fig. 36, the zinc acting as the container while the carbon is a heavy rod packed in manganese dioxide, together with some moisture-absorbing material. On the contents of the zinc container as thus filled is poured a solution of sal ammoniac and water which forms the active solution

of the battery. The cell is sealed at the top to prevent evaporation, since, when the cell does actually become as dry inside as it is outside it is no longer of any use. Some of its other characteristics are mentioned under "Ignition", Part II.

The storage battery or accumulator does not generate a current in any sense of the word. By means of a much more complicated chemical reaction than that of the primary cell it absorbs a charge of electricity. Upon the completion of the circuit of a storage cell with a suitable load or resistance, such as driving a motor or lighting a lamp, a reversal of this chemical process takes place and the battery redelivers a part of the current which it has previously absorbed. Full details of the characteristics, construction, and working of the storage battery are given in the article on "Electric Automobiles". The storage battery and the dry cell are the only two forms of battery employed on the automobile so that no mention of the other types is necessary, particularly as all but very few of them are practically obsolete.

SUMMARY OF ELECTRICAL PRINCIPLES

GENERAL PRINCIPLES

The importance of a knowledge of the fundamental principles of electricity and of its characteristics to the man who wishes to familiarize himself with the electrical apparatus on the automobile to the point where he can readily diagnose and remedy its ills has already been dwelt upon. To bring these out more clearly and make them easier to memorize, they are repeated here in the form of a brief résumé in questions and answers.

Q. What is electrical pressure, and to what may it be compared?

A. Electrical pressure is electromotive force, usually termed e.m.f., or voltage, also potential, and may be likened to water under pressure in a pipe or to compressed air in a container.

Q. Of what does this electrical pressure consist, and how is it measured?

A. It is represented by the difference of potential between two points in a circuit, and it is measured in volts.

Q. What does the unit volt represent?

A. The volt is the amount of e.m.f. required to force a current of one ampere through a resistance of one ohm.

Q. What is the ampere?

A. It is the unit of current flow.

Q. What is the ohm?

A. The unit of resistance represented by a length of wire that will pass one ampere under a pressure of one volt.

Q. In what unit is the volume of current flow measured?

A. In the coulomb, which is the equivalent of one ampere per second.

Q. Are the factors of electrical quantity, flow, and pressure related, and how?

A. They are all closely related, and their relation is governed by the factor of resistance.

Q. What is resistance, and of what may it consist?

A. Any element which tends to retard the flow of the current is resistance. It may consist of the wire of the circuit itself; the windings of different apparatus in the circuit, such as an induction coil or a motor; the filament of a lamp; a switch; or the like.

Q. Are these the only forms that resistance takes?

A. No. Poor points in wires, dirty and loose connections, dirty switch blades, all produce increased resistance in the circuit. These are undesirable increases in the resistance. In addition to these, there are special resistances intentionally inserted in the circuit to serve a definite purpose. These are known as rheostats, resistance coils, windings, or grids, according to the form they take.

Q. Why is it desirable to keep the resistance of the circuit, outside of that produced by the apparatus itself, at a minimum?

A. Because any resistance other than that interposed by the windings of the motor, the filaments of the lamps, or other useful apparatus in the circuit, not only means waste current, but also prevents the full amount of current required from reaching the desired points.

Q. How does this waste occur?

A. In a poor joint, a loose connection, or a dirty switch blade, the current is dissipated as heat and accordingly represents that much energy passing off into the air.

Q. Can undesirable resistance be interposed in a circuit in any ways other than those already mentioned?

A. Yes, by the use of wire too small to carry the amount of current required by the apparatus.

Q. What is the effect of using wires too small for the current?

A. The wires waste a great deal of the current in heat and, if much too small for the purpose, are likely to become overheated to a point at which they will burn the insulation off or to actually become fused by the current.

Q. What determines the voltage in an electrical circuit?

A. The potential, or voltage, of the source of supply, such as a storage battery, in which case the voltage will be constant less the drop caused by the resistance of the circuit; or, in the case of a lighting generator, it will depend upon the design of the latter (winding, etc.) and the speed at which it is running.

Q. How may the voltage be varied?

A. In the case of a battery, by varying the number of cells, each cell of a storage battery giving approximately 2 volts. In a generator, by varying the windings of the field and the armature and by increasing or decreasing the speed at which it runs. On a circuit having a higher voltage than desired, by the insertion of an amount of resistance calculated to give the drop required.

Q. Can lamps of a certain voltage be burned on a circuit having a higher voltage?

A. Not if inserted directly in such a circuit. For example, the standard 6-volt lamp cannot be used directly on a 6- or a 12-cell storage-battery circuit as employed for the lighting and starting systems of many cars. The filament would immediately burn out, as its thickness is calculated to a nicety to become incandescent when current of the voltage for which it is designed is passed through it, and anything in excess of this voltage will fuse the wire.

Q. How can lamps of lower voltage be used on such circuits without the employment of a wasteful resistance to cut the voltage down?

A. By cutting down the number of cells employed for the lighting, as, for example, where 12 cells are used to operate the starting motor, the battery is divided into four groups of 3 cells each for the lighting, these groups delivering current at 6 volts, while

the complete battery has a potential of 24 volts. This is termed putting the battery into *series-multiple* connection, which is explained further under the head of "Circuits".

Q. When the voltage is lower than that required by the lamp, what happens?

A. The lamp filament will give only a dull red glow with a voltage drop of but 20 per cent or less of the total, since there is insufficient potential to cause the current to bring the filament wire to incandescence.

Q. Is the insertion of any apparatus, such as lamps, a motor, etc., in a circuit having a voltage higher than that for which they are designed likely to damage them?

A. Yes, it will burn them out if, for instance, 110-volt lamps or motors are connected to 220-volt current, or 6-volt lamps put on a 12-volt circuit.

Q. Does the opposite also hold true?

A. No. The apparatus will merely fail to function properly if put on a circuit of a voltage lower than that for which it is designed.

OHM'S LAW

Q. What is Ohm's law?

A. It is the basis of all computations concerning the flow of an electric current. It is stated as *current equals voltage divided by resistance* and may be transposed to find any of the three factors, as, *resistance equals voltage divided by current*, so that, given any two of the factors, the third may be readily determined.

Q. How is the power equivalent of an electric current expressed?

A. Power equals current times voltage, the product being watts, as one volt times one ampere equals one watt.

Q. How many watts are there in a horsepower?

A. 746. Electrical horsepower, however, is usually figured in kilowatts, or units of one thousand watts, generally abbreviated to KW.

Q. Given a 6=volt storage battery fully charged and a circuit including a starting motor, the total resistance of which (idle) is .1 ohm, how much current will pass through the motor?

A. As current equals voltage divided by resistance, we have $6 \div .1 = 60$ amperes.

Q. If, instead of a heavy stranded cable between the battery and motor, we substitute a fine wire having a resistance of 10 ohms, how much current will pass?

A. Only .6 ampere.

Q. What would happen if a very small wire were employed to connect the starting motor with the battery?

A. Not sufficient current would reach the motor to operate it, and the wire would probably be fused by the heating effect of the heavy current.

Q. If one horsepower be required to turn the engine over at 100 r.p.m., and the car is equipped with a 6=volt battery, how many amperes will be necessary to start?

A. As power divided by voltage equals current, $746 \div 6 = 124\frac{1}{3}$ amperes.

Q. How is the power equivalent usually expressed?

A. Power equals current times voltage.

Q. As the voltage is one of the chief determining factors, what effect does doubling it have?

A. Reduces by one-half the amount of current required, exactly the same as doubling the pressure of a steam boiler reduces correspondingly the volume of steam necessary to perform the same amount of work.

Q. If the voltage be cut in half, what will be necessary to perform the same amount of work?

A. The number of amperes, or amount of current, must be doubled.

MAGNETISM

Q. What is magnetism?

A. It actually is electricity in another form and is evidenced by the attraction or repulsion that one magnet exerts on another, or that any piece of magnetized metal has for objects of steel or iron.

Q. How is this relation between magnetism and electricity shown?

A. By the fact that they are interchangeable. By passing a current of electricity through a coil surrounding an iron or steel bar, it becomes magnetic; upon moving a magnetized piece of metal close to a coil of wire, a current of electricity is induced in the wire.

Q. What is meant by the polarity of a magnet?

A. Upon being magnetized, a bar of steel will attract other pieces of metal (iron or steel) indiscriminately, but upon being brought close to another magnet, it will display an attraction at one end and a repulsion at the other for the second magnet. In other words, the magnetic attraction at both ends is not the same. These ends are termed the poles, one north and the other south, by analogy with the compass which is merely a magnetized needle having a natural tendency to point north and south.

Q. What other characteristics do the poles of a magnet display?

A. They show that the force of the magnet is practically concentrated at these poles, as the magnetic attraction is very much less at any other part of the bar.

Q. What is the law of magnetic attraction and repulsion?

A. Like poles repel one another and unlike poles attract. In other words, if a bar magnet be suspended, and the north pole of a second magnet be held close to the north pole of the suspended magnet, the latter will swing away; if the south pole of the second magnet be approached to the north pole of the suspended magnet, the latter will swing toward the former until they touch.

Q. How does the force of this attraction or repulsion vary?

A. Inversely as the square of the distance, i.e., separating the poles by twice the distance reduces the force acting between them to one-fourth its value. For example, if two magnets exhibit a strong attraction for each other at a distance of one-half inch, the attraction will be four times stronger when they are separated by only one-fourth inch.

Q. What are the chief magnetic substances?

A. Iron and steel.

Q. What is meant by the magnetic field?

A. The space immediately surrounding the poles and at which the magnetic force is most plainly apparent, as shown by the experiments with filings which graphically illustrate the field of influence of the magnet, and from which the term in question originates.

Q. What is a magnetic circuit?

A. The path followed by the magnetic flux, or flow, from one pole to the other.

Q. What analogy is there between the poles of a magnet and the flow of a current in an electric circuit?

A. The current is said to flow from the positive, or north, pole of a battery or generator, to the negative, or south, pole to complete the circuit, exactly as the lines of force in a magnet flow to complete the magnetic circuit.

Q. How can the polarity of a current flowing in a wire be determined by a simple experiment?

A. Hold a small pocket compass close to the wire. If the needle of the compass is attracted at its north pole to the wire, the current flowing in the latter is negative (south pole), as unlike poles attract, and *vice versa*. This will be true only when a direct current is flowing in the wire, since an alternating current, as the term indicates, alternates in polarity with every cycle.

Q. What are lines of force?

A. The invisible flow of magnetic influence from the north to the south pole of a magnet or about any conductor carrying an electric current.

Q. What is a solenoid?

A. A hollow coil of wire through which a current may be passed to produce a magnetic field.

Q. What is the difference between a permanent magnet and an electromagnet?

A. When a piece of hard steel has been magnetized, either by being rubbed on another magnet or by being placed in a solenoid through which a current is passed, the steel retains a large percentage of its magnetism when removed from this magnetic field and is said to be a permanent magnet. An electro magnet consists of a soft iron or steel core on which a coil of wire is wound. When a current passes through the wire, the coil becomes strongly magnetic, but when the current ceases, the magnetism does likewise.

Q. When a bar of iron is placed partly in the coil of a solenoid through the winding of which a current is passed, what takes place?

A. The bar is strongly attracted to the center of the coil and held there.

Q. How is this principle taken advantage of in electric starting and lighting systems on the automobile?

A. It is employed for the operation of electromagnetic switches for the starting motor, and it is also the principle upon which the electromagnetic gear shift depends for its operation.

Q. What effect has the insertion of an iron core in a solenoid?

A. It greatly increases the flow of magnetism through the solenoid, with the same amount of current passing through the winding of the latter.

Q. What effect has reversing the direction in which the current is passed through the winding of a solenoid?

A. It reverses the polarity of the latter so that if the core were a bar of hard steel, it would be drawn into the opening of the solenoid with the current in one direction, and expelled from it when the current was reversed.

Q. What bearing have the principles of magnetic attraction and repulsion and of magnetic polarity on electric generator and motor operation?

A. They are the fundamental principles upon which the operation of all electric generators and motors are based.

INDUCTION

Q. What is the principle of electric induction?

A. If a circuit carrying an electric current be opened and closed quickly in the case of direct current, and a coil of wire be held close to this circuit, a current will be induced in the coil. If the latter be wound on an iron core, the induced current will be very much stronger, and if both the active circuit and the coil are on the same magnetic core, the maximum inductive effect will be produced. The latter is, in effect, a transformer, and if an alternating current be sent through the first circuit, or coil, there is no need to make and break the circuit as where the current is direct.

Q. Why will a transformer not operate on direct current without making and breaking the circuit constantly?

A. It is necessary to magnetize and demagnetize the core, or, where there is no core, to produce a magnetic field and then destroy it, in order to produce an inductive effect.

Q. Why will it operate on alternating current without making and breaking the circuit?

A. Because the alternating current intermittently rises to its maximum in one direction, then drops to zero and rises to its maximum in the opposite direction, that is, the direction or the polarity of the current changes with every cycle. The transformer core is accord-

ingly magnetized to full strength with a certain polarity, is then demagnetized and again remagnetized with the opposite polarity, and it is this rise and fall in the strength of the magnetic field from zero to maximum, first in one direction and then in the other, that causes the inductive effect.

Q. What is a cycle?

A. It consists of one alternation from zero to maximum in one direction, back to zero and then to the maximum in the opposite direction, and back again to zero. The ordinary house-lighting supply current is 60 cycles, i.e., it alternates 60 times per second, or 3600 times per minute. It is owing to this extreme rapidity in alternation that no flickering is apparent in an incandescent lamp fed by alternating current.

Q. Where alternating current is not available, how can a transformer be operated?

A. By making and breaking the circuit at a high rate of speed, as with a vibrator used on automobile induction coils.

Q. Why is no vibrator necessary on a coil when fed with current from the magneto?

A. Because the magneto supplies an alternating current.

Q. On the so-called dual system of ignition, the same coil without any vibrator is used with both the battery and magneto as a source of current. How is this effected?

A. The circuit breaker, or interruptor, of the magneto takes the place of the vibrator when the battery is used for starting, while the alternating current from the magneto operates the induction coil, or transformer, when the engine is running on the magneto.

Q. What relation does the induced current bear to the current from the source of supply?

A. This depends upon the transformer and the purpose for which it is intended. On the automobile where it is desired to raise the current to a high voltage to enable it to bridge the gap of the spark plugs, the transformer is known as a *step-up* type, i.e., it takes current at a low voltage and transforms it to one of high voltage, or tension. The original, or primary, current passes through a winding of a comparatively small number of turns of coarse wire on a core of soft iron wires. Directly over this winding is a second one consisting of a great number of turns of very fine wire. This is known as the *secondary*

winding, and the current induced in it is termed a *secondary current*. The voltage of this secondary current depends upon the voltage of the source of supply and the proportion that the number of turns in the secondary winding bears to that of the primary winding.

Q. Is the transformer used in any other form or type on the automobile?

A. In the so-called true high-tension type of magneto, the transformer is made integral with the armature, the fine wire, or secondary winding, being placed directly over the coarser winding that serves to generate the current. The step-up is the only type of transformer used on the automobile.

CONDUCTORS

Q. Do materials differ greatly in their ability to conduct electricity, and which are the most efficient in this respect?

A. They vary all the way from absolute insulators to those metals which will pass the electric current with the minimum resistance, such as silver, copper, and aluminum.

Q. Do the characteristics of a material affect its current-conducting ability?

A. Very greatly. The harder copper is, the poorer its conductivity, and this is likewise the case with steel.

Q. Name the different materials in the order of their current-conducting ability.

A. Silver in pure state, soft copper, brass, aluminum, iron, steel, carbon, German silver, etc.; also water, depending upon how alkaline or acid it is.

Q. Is German silver a good conductor?

A. No. It is known as *high-resistance* conductor and is accordingly used chiefly for winding resistances and not for the wires of a circuit.

Q. What are some good insulators?

A. Wood, glass, resin, paraffin wax, silk, cotton, asbestos, rubber, and similar mineral or vegetable substances.

Q. Are they always equally good imsulators, regardless of their condition?

A. They are efficient as insulators only when dry. The presence of moisture on any of them affords a path for the current to cross them.

Q. What effect on the ability of the conductor to carry a current has the amount of material used?

A. The resistance is increased with a decrease in size and is also increased directly as the length of the conductor.

Q. Where, for mechanical or other reasons, it is not practical to use copper or aluminum, how can an equally efficient conductor of some other material be provided?

A. By increasing the amount of material employed in the same proportion that its conductivity bears to that of copper. For example, assuming that steel is only one-thirtieth as good a conductor as copper, thirty times as much of it must be employed to give the same conductivity.

Q. Give an example of this?

A. The single-wire system of connecting the starting and lighting outfit on an automobile. A small copper cable forms one side of the circuit, while the entire chassis forms the other. The ordinary trolley-road circuit is another, the small overhead wire forming one side of the circuit, and the rails on which the car runs, the other.

Q. Name some of the materials which are employed for their high resistance to the current.

A. German silver, iron wire, cast iron in the form of grids of small cross-section, and carbon. Very fine copper wire is also employed where the resistance desired is not very great, and space considerations permit its employment.

Q. What is meant by the "specific conductivity" of a material?

A. Its ability to conduct the current as compared with that of pure silver which has a specific conductivity of one.

Q. Does this ability of a conductor to convey the current vary particularly with a great increase in voltage?

A. Yes. The so-called high-tension current which has been stepped-up in a transformer from the 6-volt potential of the 3-cell storage battery to many thousand volts for ignition purposes will cross surfaces and penetrate materials that are perfect insulators to the low-tension current. For example, the high-tension current will leak across a moist wooden surface or it will sometimes puncture the one-fourth inch of rubber and cotton insulation of the secondary cable.

Q. What is one of the chief effects of transforming a current at a low voltage to one of high potential?

A. It enables the current to leap an air gap, the width of which is proportioned to the voltage itself. The greater the voltage the greater the width of the gap it will jump. This is the principle on which the spark plug is based.

HIGH-TENSION CURRENTS

Q. When a current of 2 amperes at 6 volts, such as would be consumed by the ordinary ignition coil from a storage battery, is transformed to a high potential, is the amount of current still the same? In other words, can 2 amperes at 6 volts be transformed or stepped-up to 2 amperes at 10,000 volts?

A. No. The current decreases as the voltage increases. For example, to make the comparison more clear, consider a current of 10 amperes at 100 volts. This is passed through a step-up transformer, of which the ignition coil is a type, and is given a potential of 1000 volts. The current, however, would then be 1 ampere, that is, the current decreases in the same proportion that the voltage is increased. The opposite is also true. By passing this current of 1 ampere at 1000 volts through a step-down transformer, it may be converted into a current of 100 amperes at 10 volts. It will be noted that the product of volts times amperes in any of the above instances cited, or of any possible combinations that can be made, is always the same. In other words, a certain amount of energy is sent through the transformer, and the same amount, barring losses due to the transformation process itself, is taken out.

Q. Is there any mechanical analogue of this process of transforming a current up or down to impress upon it a greater or lesser potential?

A. There is nothing in mechanics that corresponds exactly to this peculiar property of electricity. The resulting change in the form in which the energy is applicable as a result, however, may readily be compared with mechanical standards. For example, we may have in a very small boiler, a pressure of 1000 pounds to the square inch, but a volume of only one cubic foot of steam. This small amount at its high pressure represents the equivalent in energy of 10 cubic feet of steam at a pressure of 100 pounds.

Q. What is the object of stepping the current up to such high voltages?

A. On the automobile, simply to enable it to jump the gap of the spark plug and fire the charge. In ordinary commercial service, to permit of sending it long distances with a minimum expenditure for copper wire and a minimum loss in the amount of energy transmitted.

CIRCUITS

Q. What is meant by an electric circuit?

A. The path by which the electrical energy, or current, is said to flow from and return to its source.

Q. Is a circuit absolutely necessary in order to permit of utilizing electricity?

A. Unless there is a circuit or complete path for the current, it does not flow.

Q. Must a circuit be comprised completely of wires leading from, and returning to, the source, such as the battery or generator?

A. No, it is not necessary that wire be used for both sides of the circuit. One side or the other may be composed of a *ground*, such as the tracks of a trolley system, the overhead wire constituting the other side of the circuit, or in the case of a single-wire lighting and starting system in which one cable is employed to conduct the current from the battery to the starting motor and lights. and the chassis itself forms the ground return for both.

Q. How many forms of circuits are there in general use?

A. Three: the series, the multiple, and the series-multiple. In the first, all apparatus in the circuit is in series. That is, all the current from the source must pass through each instrument or light in turn to complete the circuit. In the multiple type of circuit, every instrument or light on it is independent of all the others. Lights may be turned on or off, motors started or stopped, without interfering in any way with any of the others. As its name indicates, the series-multiple is a combination of the two forms of circuits. For example, in using incandescent lamps to cut down the current for charging a storage battery from the lighting mains, the lamps themselves are in multiple, but the whole bank of lamps is in series with the storage battery. See illustration on charging storage battery direct from lighting mains.

Q. Which of these forms of circuit is in most general use on the automobile?

A. All three will be found on practically every car equipped with a starting and a lighting system. For instance, the starting motor is operated in series with the battery, while the lamps are wired in multiple for the side and head lights, and the speedometer and tail light are wired in series as a branch of the multiple-lighting circuit, thus giving a series-multiple circuit. The ignition distributor, coil, and battery are in series.

Q. What is meant by a grounded circuit?

A. This is ordinarily used to indicate that through lack of insulation at some part of the wire, or similar injury, the circuit has been shortened, owing to this bare wire touching a *ground*, thus permitting the current to return to its source without passing through whatever instruments there may be on the circuit. A *grounded circuit*, however, is also one in which one side consists of a ground return instead of having two wires. This is frequently distinguished by being termed a *ground-return* circuit.

Q. What is a short=circuit?

A. As the term indicates, a completion of the circuit short of the point or apparatus which the current is intended to reach. The example just cited is a short circuit as well as a ground, sometimes termed a *grounded short-circuit*. In other words, the abrasion of the insulation of one of the conductors has permitted the current to escape by a convenient path of return which, being of less resistance than the one it is intended to take, prevents any current from reaching the apparatus in the circuit. A ground is practically always a short-circuit, but the reverse is not always true, that is, a short-circuit need not necessarily be a ground, as in a double-wire circuit, but the two conductors may come together at a point where the insulation is worn, or winding of a coil may break down and cause a short-circuit.

Q. What are some typical examples of grounded circuits on the automobile?

A. Both the primary and secondary sides of the ignition circuit and the starting and lighting circuits of the so-called single-wire systems in which the chassis is always used as a ground return for all the circuits employed.

HYDRAULIC ANALOGUE

Q. What is a hydraulic analogue, and what bearing has it on an electrical system?

A. It is a comparison of the electrical system with a hydraulic or water-pressure system and serves to make clear the resemblance or analogy that exists between the principles upon which both operate.

Q. What type of hydraulic system is similar to an electrical system consisting of a generator, external circuits, and lamps, motors, or the like, as a load?

A. A constant-pressure system in which the pumps keep the water in the pipes under a certain amount of pressure corresponding to the demand. When the demand increases, the supply does likewise and *vice versa*. (In the case of the pumping system, this is not automatic, but is controlled by the attendant.)

Q. To what does the pressure of such a pumping system correspond in the electrical system?

A. To the voltage, or electromotive, force.

Q. Can there be voltage, or potential, in an electrical system without a flow of current?

A. Yes, exactly as in the pumping system in which there is always a constant pressure on the water in the pipes whether the water is escaping through any of the outlets or not. In other words, there may be pressure but no flow. The same thing is true of the generator. If it be turning at its normal speed and is wound to produce current at 100 volts, there will be a potential of 100 volts across its terminals, even though there are no lamps or motors switched on in the external circuit.

Q. How does the resistance of the pipe lines in the water system compare with the resistance of the wires in a circuit to the electric current?

A. It is nearly the same. It varies inversely as the size of the pipe and directly as its length. The smaller the pipe the greater the resistance per foot; the longer the pipe the greater the total resistance. In the same way, the resistance to the electric current increases with the decrease in the size of the wire and increases with the length of the wire, the chief difference being that bends or turns in the wire do not add to the electrical resistance, whereas bends in the pipe impose greatly added resistance to the flow of water.

Q. What comparison may be made between the speed at which the generator and the pumps run?

A. The greater the speed, the greater the pressure in the case of the pumps, and of the voltage in the case of the generator. Below a certain speed, usually termed the normal speed, there is a sharp falling off in the pressure in both. Neither can be operated safely at an excessive speed.

Q. What is the cause of the increase in voltage with increasing speed in the case of the generator?

A. Voltage, or electromotive force, is generated by the coils, or windings, of the armature cutting the magnetic lines of force of the field of the generator. The greater the number of times that these coils pass through the lines of force per minute, the greater the voltage will be.

Q. How does fall in pressure correspond to voltage drop?

A. To reach the end of the piping system, the water must overcome the resistance of the latter to its passage, and the friction involved robs it of some of its pressure in overcoming this resistance. Consequently, there is less pressure at the outlet a mile away from the pumps than there is at the pumps themselves. The same thing is true of the electric circuit. The current must force its way through the wires by reason of its voltage or pressure and, in so doing, some of the voltage is lost in overcoming the resistance of the wires, joints, switches, and the like. In both cases allowance for this loss is made by increasing the pressure at the source by an amount equivalent to the loss in transmission. For example, in electric street-railway work the motors are wound to operate on current at 500 volts, while the generators in the powerhouse produce current at 550 to 600 volts, the difference being known as the *voltage drop*.

Q. Is this an important matter on the automobile where the circuits are so short?

A. It is of considerable importance, particularly in connection with the starting motor circuit. The circuits are very short, but the initial voltage is likewise very low, so that the percentage available for voltage drop is correspondingly limited. For example, a drop of one volt in a 110- to 115-volt lighting circuit is negligible, being less than 1 per cent, but a drop of one volt in a 6-volt circuit represents almost 17 per cent and would accordingly be prohibitive. As poor

connections, dirty switch contacts, dirty commutator, and worn brushes are apt to increase the resistance to a point where the voltage drop is in excess of this, the importance of properly maintaining these parts of the system may be appreciated.

Q. How does the flow of water correspond to the flow of current?

A. In both cases, the amount is proportionate to the resistance of the outlet and to the pressure back of the current, whether water or electricity. In other words, the volume of water that will flow depends upon the size of the outlet (the smaller the outlet the greater the resistance to the flow) times the pressure back of it. In the same way the number of amperes that will flow when the circuit is closed depends upon the voltage of the circuit divided by the resistance (Ohm's law). For example, the ordinary 16 c.p. carbon-filament lamp for a 110-volt circuit has a resistance of 220 ohms, which, divided by 110, gives $\frac{1}{2}$ ampere as the current that will flow when the lamp is switched into the circuit.

Q. Can the piping system properly be compared with an electric circuit?

A. In practically every way except that of the return required for the latter. For example, the opening of a series of outlets in the piping system reduces the pressure in proportion to the number opened; so in connecting a number of different pieces of apparatus in series in an electric circuit, the voltage through each will decrease as another is added. It may also be compared with a parallel or multiple circuit in that the opening of one outlet does not prevent drawing water from another. A break in a main corresponds to a short-circuit or a ground in that no water can then be drawn from any outlet beyond the break. The comparisons between the piping system and the circuit are not exact, owing to the lack of any necessity for a return in the case of the water piping, but they serve to make clearer some of the fundamentals of the electric circuit.

GENERATOR PRINCIPLES

Q. What makes it possible to generate a current of electricity by mechanical means?

A. The fact that electricity and magnetism are different manifestations of the same force and that, given one, the other may be

produced. Also the fact that they are readily interchangeable, i.e., one may be readily converted into the other.

Q. On what fundamental principle does the generation of electricity in this manner depend?

A. That of induction.

Q. How is it utilized?

A. By revolving a coil of wire in the field of a magnet.

Q. What occurs when this is done?

A. An e.m.f. is generated in the coil.

Q. Describe the simplest form of generator.

A. Such a generator consists of a horseshoe magnet between the poles of which a coil of wire is revolved.

Q. What governs the strength of the e.m.f. or potential, thus generated?

A. The speed with which the conductor or wire revolves, or is said to "cut the lines of force" of the magnetic field.

Q. How can this potential be further increased?

A. By winding the coil of wire on an iron core, as the iron becomes strongly magnetic and greatly increases the inductive effect.

Q. What is this simplest form of generator consisting of horseshoe magnets for the field and of a single winding on an iron core termed, and for what is it employed on the automobile?

A. It is known as a *magneto* and is generally employed for producing the current needed for ignition purposes.

Q. Can such a generator be directly employed for charging a storage battery or for lighting lamps?

A. No, it cannot be used for charging purposes, since it generates an alternating current. Moreover, owing to the small number of poles (two), its single winding, and the high speed at which it is driven, it produces very little current but a high e.m.f., as this is desirable for ignition. It cannot be used for lighting purposes for the same reason, i.e., the simple winding produces an alternating current with a very perceptible interval between the alternations, or cycles, so that a lamp would flicker very badly. As its e.m.f., or voltage, is proportionate to its speed and as there is no method of controlling it, the lamp would be burned out as soon as the magneto was speeded up.

Q. What are the essentials of this simple form of generator?

A. The field consisting of the horseshoe magnets, and the armature consisting of a soft iron or steel core, usually in the form of an **H**, in the slots of which, the single winding of comparatively coarse wire is wound.

Q. Why is the field of a magneto usually referred to as a "permanent field?"

A. Because it consists of so-called permanent magnets. Naturally, they are not permanent in the real sense of the word, but their magnetism is constant while it lasts and it decreases only very gradually under the influence of heat and vibration.

Q. Why does heat affect the magnetism of the field of a generator of this type?

A. Because a piece of hard steel that is strongly magnetic when cold loses its magnetism altogether when raised to a sufficiently high temperature. In other words, if heated to a bright red and then cooled, it is no longer a magnet, and the steel must be remagnetized. Constant vibration has the same effect, but it is much slower.

Q. Is there any other way of increasing the voltage of such a generator besides running its armature at a higher speed?

A. Yes, by increasing the number of turns of wire in the winding, which has the same effect as revolving a single coil at a higher speed.

Q. How is the current produced by a simple form of generator, such as the magneto, conducted to an outside circuit?

A. Ordinarily, this would be done by means of slip rings, i.e., plain bands of copper mounted on the armature shaft with narrow copper brushes bearing on these rings, as is the case with large alternating-current generators. But as the ignition system of the automobile is a grounded circuit, one end of the armature winding of the magneto is connected directly to the core of the armature, and the other is led to a small V-shaped ring or to an insulated stud on the end of the shaft against which either a copper or a carbon brush is held by a small spring.

Q. What is the cause of the alternating cycle of the magneto, and at what points in the revolution of the armature does it occur?

A. In revolving in the field of the magnets, the armature passes successively from the field of influence of a north pole to one of opposite polarity, so that the direction of the e.m.f. is reversed.

When the armature is in a horizontal position in the field, the e.m.f. curve is at zero; as it turns, the edges of the armature core pass the ends of the pole pieces of the field, and the e.m.f. rises sharply to a maximum as the central line of the core passes the ends of the poles, when it is said to be cutting the maximum number of lines of force. It drops off again quickly from this point and again reaches zero, when the armature is in a vertical position. As its ends come under the influence of opposite poles, the curve again rises, but is now in the opposite direction, or of opposite polarity. In other words, it passes from zero to maximum and back again in every half revolution, or 180 degrees.

Q. How can a generator be made to produce a direct, instead of an alternating current?

A. The current is always alternating as generated in the armature, but it may be conducted to the outside circuit as a unidirectional, or so-called direct, current by the addition of a commutator.

Q. Can such a current be produced by the addition of a commutator to the simple single-coil winding already mentioned in connection with the magneto?

A. Yes, but as the commutator would have but two parts, the e.m.f., while passing in one direction, would be strongly pulsating.

Q. What is a commutator and how does it convert the alternating current produced in the armature to a direct current in the outside circuit?

A. It consists of a number of segments of copper, one for each coil terminal of the armature, i.e., two for each complete coil of the winding. These segments are insulated from one another, and brushes bear at opposite points of the conducting hub thus formed by the segments. As the terminals of the armature coils are connected to segments that are opposite one another (in the simplest forms of winding), and as the brushes, also opposite one another, are set at points so that they pass from one segment to another when the rate of cutting is at a minimum in the armature winding, their relation to the latter is changed each half revolution. In other words, at the point in the revolution where the polarity of the e.m.f. generated reverses, the relation of the brushes to the winding is also reversed, so that the direction of the e.m.f. is accordingly always the same. See Figs. 20 and 21.

Q. How is the pulsating nature of the direct current thus generated overcome?

A. By adding coils and commutator bars to the armature so that new coils come into action before the e.m.f. produced in those just preceding them under the brushes has an opportunity to drop much below the peak or maximum. Thus, only the peak of the wave is utilized, and the e.m.f. of a direct current consists of a series of these wave peaks overlapping one another.

Q. Are permanent magnets used for the fields of all generators?

A. No, only for those of magnetos. In other types, an electromagnetic field is used.

Q. What are the advantages of the permanent field for use in connection with the magneto?

A. It is always at its maximum strength, so that the magneto generates a powerful e.m.f., even though turned over very slowly. Regardless of the speed of the armature, the strength of the field remains the same, so that no controlling devices are necessary to prevent the armature from burning out, owing to excessive speed.

Q. What is an electromagnetic field and how is it produced?

A. It is based on the fact that when a current of electricity is sent through a winding surrounding an iron core, the core becomes strongly magnetic. It accordingly consists of windings on the fields of the generator, in addition to those on the armature. Depending upon the particular type of generator in question, either all or only part of the current produced in the armature is sent through the windings of the field. The latter is then said to be *self-excited* in that it depends upon no outside source.

Q. Is the self-excited field characteristic of all generators except the magneto?

A. Yes, of all direct-current generators. Large alternating-current generators are said to be separately excited, a smaller direct-current generator being employed solely for the purpose of rendering the fields of the larger machine magnetic.

Q. What is a series-wound generator, and why is this type not used on the automobile?

A. It is one in which the entire current generated in the armature is passed through the field windings. It does not generate until a high speed is reached. Its voltage varies sharply as its speed, and

it may have its polarity reversed by the battery if its speed drops below a certain point, consequently, it is not fitted for charging storage batteries. (In fact, the series-wound generator is practically obsolete, except for some special uses.)

Q. What are shunt= and compound=wound generators?

A. In the former, the windings of the armature and of the fields are in multiple, or shunt, so that only a certain amount of current, depending upon the difference in the resistance of the outside circuit and that of the fields, passes through the windings of the latter. As the load and consequently the resistance of the outside circuit increases, more current passes through the shunt, and the fields become more strongly magnetic, thus increasing the output so that the generator is, to a certain extent, self-regulating.

In the compound type, there is, in addition to the main shunt winding on the fields, an auxiliary winding of heavier wire (lower resistance) which is connected in series with the armature. As in a series-wound generator, the amount of current exciting the fields is directly proportional to the speed, more current in proportion passes through the compound winding than through the shunt winding as the load is increased, and the generator is self-regulating to a much greater degree. The compound-wound type of generator is in practically universal use on the automobile as well as for general power purposes. See Figs. 31 and 32.

Q. What is meant by the term "self=regulating" as used in the preceding paragraphs?

A. The generator automatically produces more current in response to the demand occasioned by an increase in the load, without any change in its driving speed.

Q. How is this accomplished?

A. The amount of current produced by the generator depends upon the strength of its magnetic field in which the armature revolves. The magnetism of this field represents the so-called lines of force. The greater the number of lines, or the more powerful they are per unit of pole-piece surface, the greater the volume of current that will be generated. In practical usage, this is referred to as the *magnetic flux*, or flow, through the armature. By increasing or decreasing the amount of this magnetic flux through the armature, the current output can be controlled within close limits.

Q. What is meant by the "load" on a generator?

A. The lamps, motors, storage battery, or similar apparatus to which it is supplying current.

Q. As the speed of the generator itself does not increase, how does it provide for an increase in the load?

A. By absorbing more power from its driving unit. For example, if a generator be operating with only ten 100-watt lamps in the circuit, it is requiring approximately one and one-half horsepower to drive it. Now, if another group of ten lamps of the same size be switched on, the amount of power demanded by the generator of its engine will be doubled. This may be very readily demonstrated in a rough way by fitting a handcrank to any small automobile generator and turning the machine over with one lamp in the outside circuit. It will be found very easy to spin the generator very rapidly by hand, as practically no resistance is felt. Now connect in the circuit a discharged storage battery, and the additional power required to turn the machine will at once be very perceptible.

Q. What are the brushes and what purpose do they serve?

A. They are strips of copper or carbon (the latter is now almost universally used), which serve to conduct the current generated in the armature to the outside circuit and to the field windings by bearing on the revolving commutator. Except where an additional brush is employed for regulating purposes, there is usually one brush for each pole of the field, i.e., a bipolar generator is fitted with two brushes, a four-pole with four brushes. The brushes are held against the commutator by springs. Soft copper embedded in carbon is also employed, especially for low-voltage generators, such as the lighting generator on the automobile.

ELECTRIC MOTORS

Q. Is there any difference in principle between the electric generator and the electric motor?

A. Fundamentally, they are the same, as is evidenced by the fact that either is reversible, that is, an electric generator, when supplied with current from an outside source (of the proper voltage, of course), will operate as a motor, and a motor, when driven by an outside source of power, will generate an electric current. They are naturally not interchangeable in practice, owing to differences in

design and winding. The generator is wound to produce the maximum amount of current at a certain voltage with a given horsepower, while the motor is designed to produce the maximum amount of power with the minimum current.

Q. What is the operative principle of the electric motor?

A. That of magnetic attraction and repulsion.

Q. How is it applied?

A. As in the generator, both the fields and the armature of the motor consist of electromagnets. The brushes and the commutator serve the same purpose of reversing the direction of the current through the armature coils every time a different pair of commutator segments passes under the former. As has already been explained, reversing the direction of current flow through the winding of an electromagnet reverses the polarity of the magnet itself. To simplify the illustration, take a bipolar motor with a two-pole armature having but a single winding. When the current is switched on, the armature is at a 45-degree angle, so that its poles are just under the poles of the field. As the commutator causes the current to flow through the armature winding in a reverse direction to that of the fields, unlike poles will be created. They will attract each other, and the armature will revolve a small part of a revolution, until it is directly in the strongest part of the field of the influence of the field magnets. Just as this point is reached, however, the brushes pass on to new segments of the commutator, and the direction of the current in the armature coils is instantly reversed. The polarity of the armature core is also reversed, so that there are now like poles opposed to one another, and they repel, causing the armature to complete another part of its revolution, when the former conditions are again established and the armature is again attracted. In a bipolar motor with a simple two-pole armature, there would be two phases of attraction and repulsion per revolution. In larger motors this is multiplied by the number of poles in the field and the number of coils on the armature.

Q. As an electric motor in running fulfills all the conditions necessary for the generation of an e.m.f., what becomes of this voltage?

A. It constitutes what is termed a *counter e.m.f.* and serves the useful purpose of increasing the resistance of the motor when in

operation, thus reducing the amount of current necessary to drive it. For example, when the motor is standing idle, the resistance of its windings is low. It is for this reason that large direct-current motors (one h.p. or over) cannot be started without the aid of an outside resistance to cut down the starting current, otherwise the armature would be burned out. As the armature speeds up, the counter e.m.f. generated opposes that of the driving current and accordingly increases the resistance. The heating of the windings in operation further serves to increase the resistance, as the resistance of most metals increases with a rise in their temperature.

Q. How many types of motors are there, and what type is most generally used for automobile starting?

A. As they correspond exactly to generators, there are the same number of types, i.e., series, shunt, and compound wound. The series type is almost universally employed on the automobile and is also very largely used on trolley cars.

Q. If the series=wound generator is of so little practical applica=tion, how is it that the series=wound motor is found so advantageous?

A. The same characteristics that are a disadvantage in the generator are correspondingly valuable in a motor, which explains why generators and motors are not interchangeable in practice, as already mentioned. A series-wound machine is essentially a variable-speed machine, and this is not desirable in a generator, while it is in a motor. The series type of motor has a very heavy starting torque, or pull, which increases as the speed of the motor decreases. This is exactly what is wanted to overcome the inertia of the gasoline engine. Its current consumption falls off very quickly as its speed increases, and it has a very liberal overload capacity, being capable of carrying loads up to five times the normal, for short periods.

Q. As the speed of the series motor decreases in proportion to the load, what happens when the load is suddenly relieved as in the starting of the gasoline motor?

A. The electric motor tends to race, or *run away.*

Q. How is this prevented on the automobile?

A. The method employed differs in different systems, but, as a rule, the starting of the gasoline engine automatically opens the starting motor circuit, or means are provided for greatly reducing the amount of current it receives the moment the load is removed.

Q. Are either shunt= or compound=wound motors used on automobiles?

A. They are employed on electric vehicles, but not in connection with the starting systems used on gasoline cars.

Q. What is a motor=generator, and what is it employed for?

A. As its name indicates, it consists of two units, a motor and a generator, the former having an alternating current, and the latter a direct current. It is employed for converting an alternating current into a direct current, so that it may be utilized for charging storage batteries. The alternating-current supply is used simply for running a motor of that type to which is directly coupled a direct-current generator. There is no electrical connection between the two machines.

Q. Are motor=generators ever used on automobiles?

A. No, but the combination of a direct-current generator and a starting motor in one machine, as in the single-unit systems, is frequently so-called through error. This single unit is variously termed a *dynamotor* and a *genemotor* to distinguish it from a motor-generator.

Q. How are the two radically different purposes for which the generator and the motor must be designed combined in one machine?

A. By putting independent windings on the fields and the armature, and, in some instances, by employing two commutators at different ends of the armature shaft.

BATTERIES

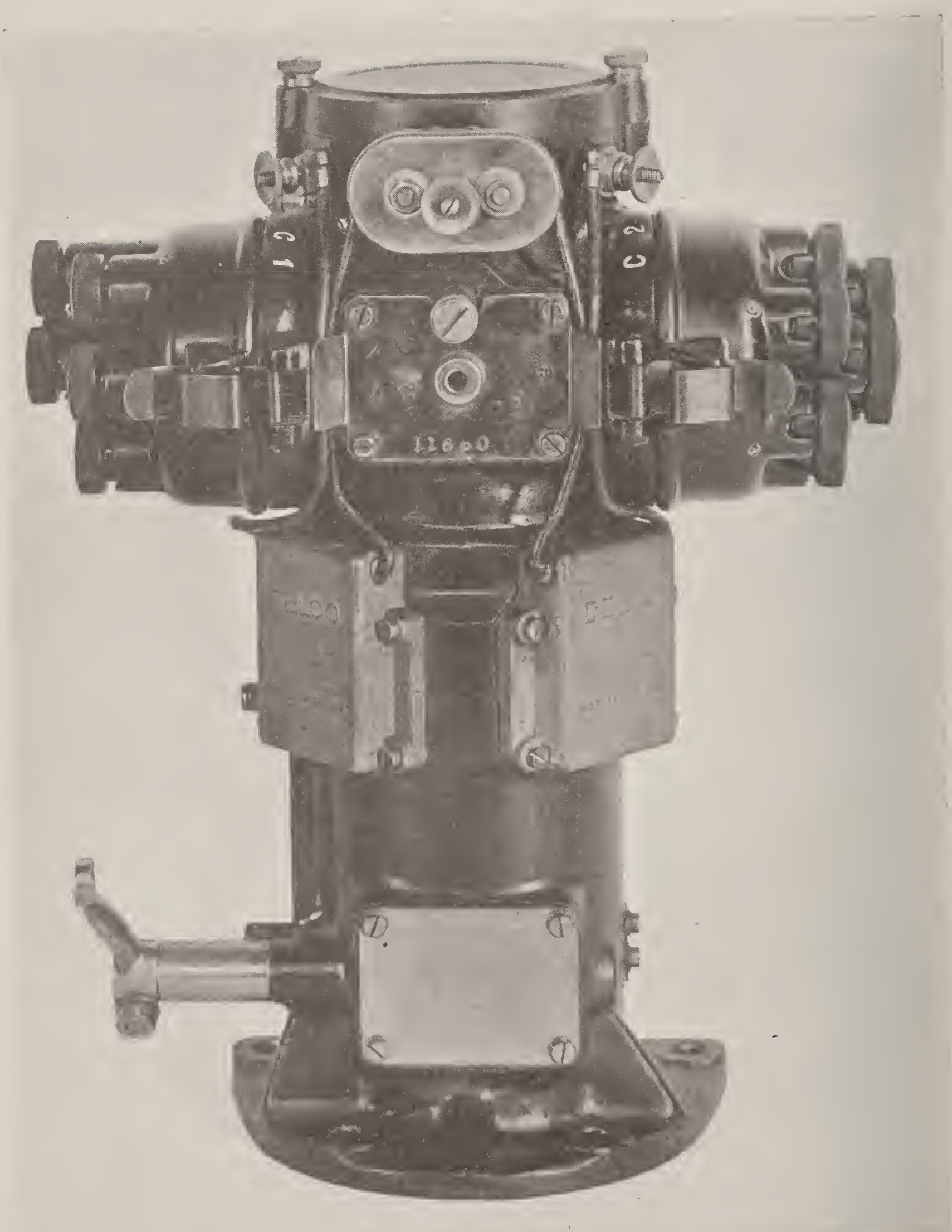
Q. What other method is there of producing an electric current besides that of driving a dynamo?

A. The use of batteries known as primary and secondary cells.

Q. What is the difference between these two types?

A. In the primary cell, the current is generated by means of the chemical reaction taking place between electrodes of different materials in an acid or alkaline solution, one electrode being dissolved in the solution as the chemical action continues.

The secondary cell is the storage battery. This does not generate a current of electricity as in the case of the primary cell, nor does it actually store electricity as its name would indicate. The passing of a current through its elements brings about a chemical conversion of the latter, which is reversed when the current flows out of the cell.



DELCO DISTRIBUTOR FOR PACKARD "TWELVE" ENGINE
Courtesy of Dayton Engineering Laboratories Company, Dayton, Ohio

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART II

IGNITION

FUNDAMENTAL IGNITION PRINCIPLES

Faulty Ignition Cause of Much Early Trouble. More than half of the troubles encountered by the designers and the drivers of the early automobiles were the direct results of the extremely crude ignition systems at first adopted. With knowledge of gasoline-motor operation generally scant at that time, much of this trouble was attributed to causes entirely foreign to its real source or, on general principles, the motor was roundly "cussed" as a deep and unfathomable mystery. Subsequently it became plain that much of this inexplicable tendency to balk was due to the elusiveness of the electric current. Crude insulation and contacts, inherently defective spark plugs, and extremely wasteful current-handling devices, fed from a weak source, were the causes.

Distinctions between Low Tension and High Tension. A low-tension ignition system uses a low-tension current—i.e., the output of a battery or small generator, employed at the voltage at which it was produced, or, in other words, a primary current. A high-tension uses a high-voltage current produced by passing the output of the battery or other source of supply through a step-up transformer (induction coil). As this is taken from the secondary winding of the coil, it is sometimes referred

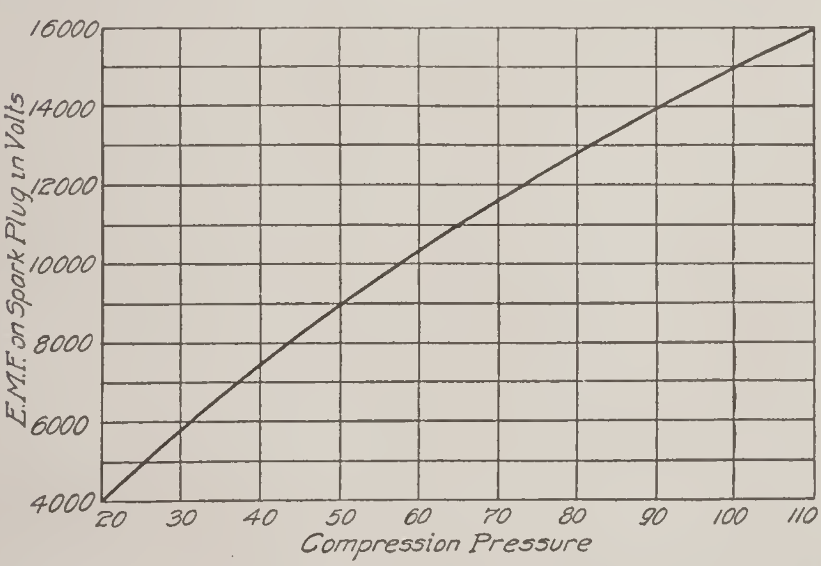


Fig. 37. Voltage Required to Force a Spark Across a .020-Inch Gap Under Different Compression Pressures

to as a secondary current It is the result of induction and is commonly termed a high-tension current owing to its great voltage or potential. The battery produced current of high amperage value at 6 to 8 volts, which after being passed through the coil became a current of microscopic amperage value at anywhere from 10,000 to 25,000 volts, according to what the designer of the coil thought was sufficient potential to produce a good spark, that is, to enable it to readily jump the gap in the points of the plug. The curve, Fig. 37, shows the voltage necessary to force a spark across a given distance in air under various pressures.

As the low-tension current will not jump an air gap, a further distinction between the two systems is the employment of totally

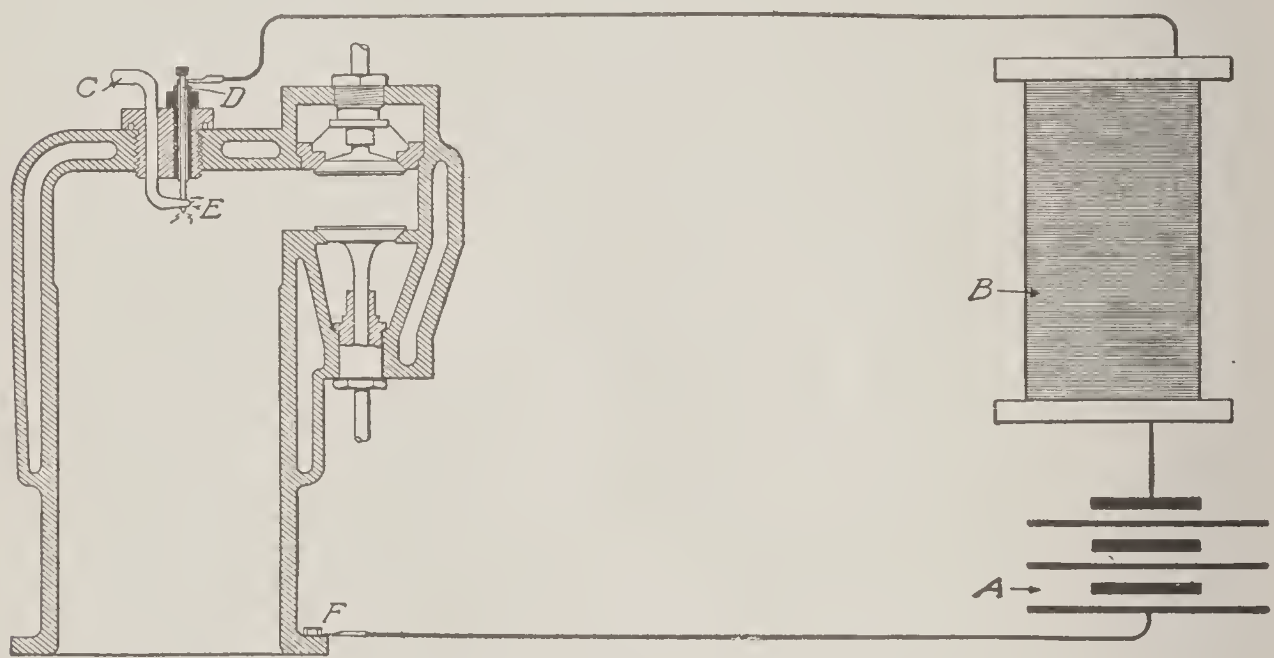


Fig. 38. Diagram of Low-Tension Ignition System

different types of spark plugs. In the former, a mechanically operated plug, i.e., one that is held closed until the maximum current is passing through it and is then suddenly opened by being mechanically tripped by a cam or rod operated by the engine, is essential. Such a plug produces a spark that is immensely superior in heating value and, consequently, in igniting ability, to the usual thin spark that bridges the gap of a high-tension spark plug. But this most desirable quality is likewise quickly destructive of the contact points, necessitating frequent readjustment of the mechanically operated plugs. Moreover, the mechanical lag or time element of operation, due to the inertia of the numerous moving parts, rendered it difficult to make a low-tension spark plug suitable for a high-

speed engine without resorting to the most expensive machine work, and much greater skill was necessary for their proper adjustment.

The shortcomings of the original high-tension systems were so glaring, however, that some of the most successful automobiles of earlier days were fitted with low-tension ignition.

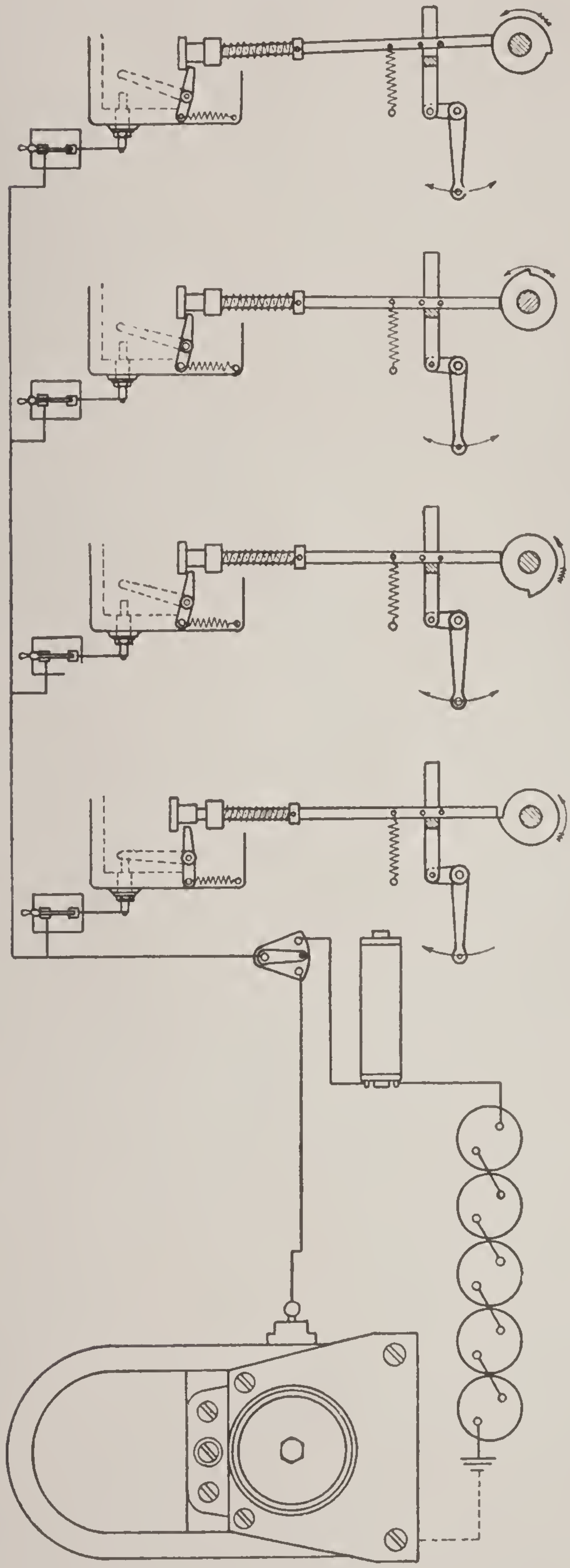


Fig. 39. Four-Cylinder Low-Tension Ignition System (*Horseless Age*)

Low-Tension System. Fig. 38 shows diagrammatically the essentials of a low-tension system for a single-cylinder motor, while Fig. 39 shows a complete low-tension system for a four-cylinder motor. The details of the operating mechanism and the plug are shown in Figs. 40 and 41. Referring to Fig. 38, *A* is the battery (a magneto, dynamo, or any other suitable source of current may be used), *B* is a spark coil, and *C*, *D*, and *E* are the elements of a make-and-break device that is mechanically actuated at regular intervals by the motor itself to produce the sparks within the cylinder. As shown in the drawing, the circuit is completed by grounding the wires from one side of the battery on the cylinder base, or any other portion of the machine, as at *F*. In this figure *D* is a small insulated plug entering the interior of the cylinder, usually through one of the valve caps, while *C* is a movable arm (see also Fig. 40), that makes and breaks contact with *B*, at the point *E*, when it is given a

slight rocking movement. For the best results this rocking movement must be very sharp and rapid, in the nature of a snap, and it must, of course, be correctly timed to occur in proper relation to the moment when the spark is required. (See also Fig. 41.)

The chief advantage of low-tension ignition is its immunity from troubles caused by short-circuiting by leakage of the current through poor insulation or across moistened terminals. This led to its almost universal employment on motor boats for a number of years, but it has since been generally abandoned even for marine use so that it is now only to be found on stationary engines, the low rotative speeds of which make it practical. So far as the automobile is concerned, the low-tension system is only of historical interest as it is already several years since it was wholly discarded.

High-Tension System. High-tension ignition systems are based on the fact that when a sufficiently high potential is impressed upon a current of electricity, it will leap an air gap or other break in the circuit of a width dependent upon the potential or voltage itself. In bridging such a gap, the current becomes visible in the form of an arc, flash, or spark, depending upon its duration and intensity, and it will readily ignite a gasoline or other gaseous fuel mixture. Its

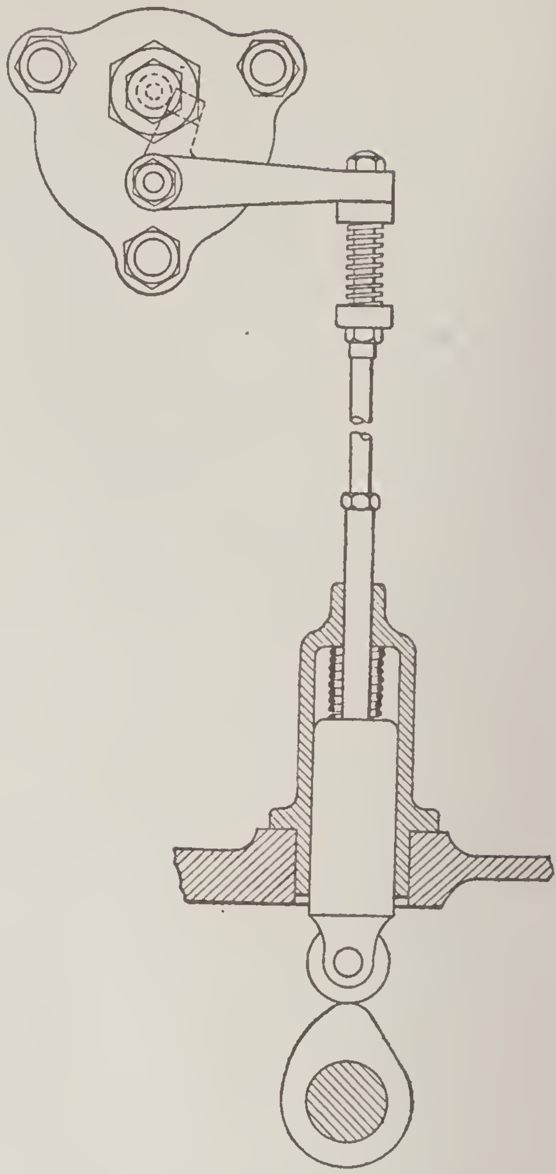


Fig. 40. Make-and-Break Mechanism

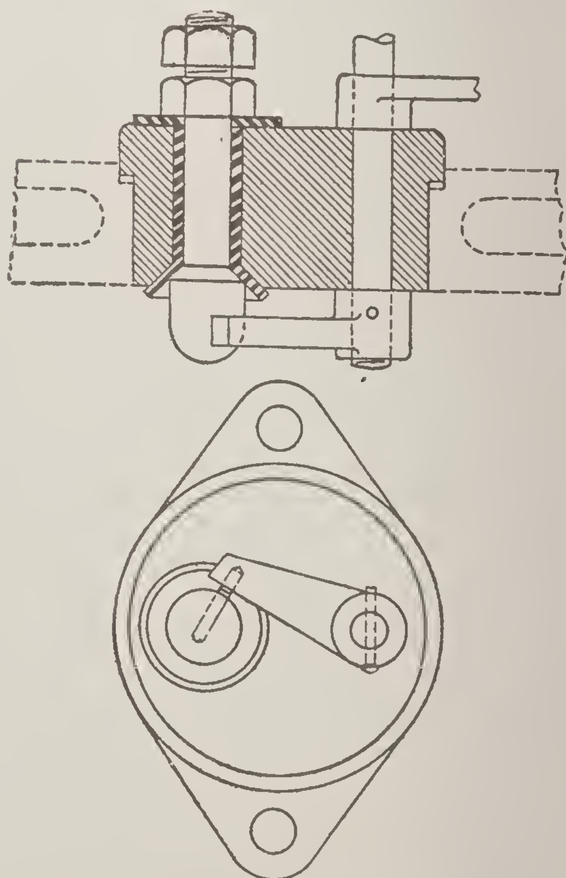


Fig. 41. Low-Tension Spark Plug
(*Horseless Age*)

very ability to do so, however, was one of the most prolific sources of trouble in the early days, as the designer's conception of the insulation required to conduct such a current without grounding or short-circuiting was far from approaching the reality.

The essentials of a high-tension system are shown diagrammatically in Fig. 42. *A* is the source of current, usually a battery in earlier days, as indicated by the conventional sign, placed in a primary circuit that also includes the contact maker *C*, the primary winding of the coil *B*, and the vibrator *G*. The contact maker *C* is positively driven by a connection with some revolving part of the motor, so that it makes contact at the exact time ignition is required in each cylinder.

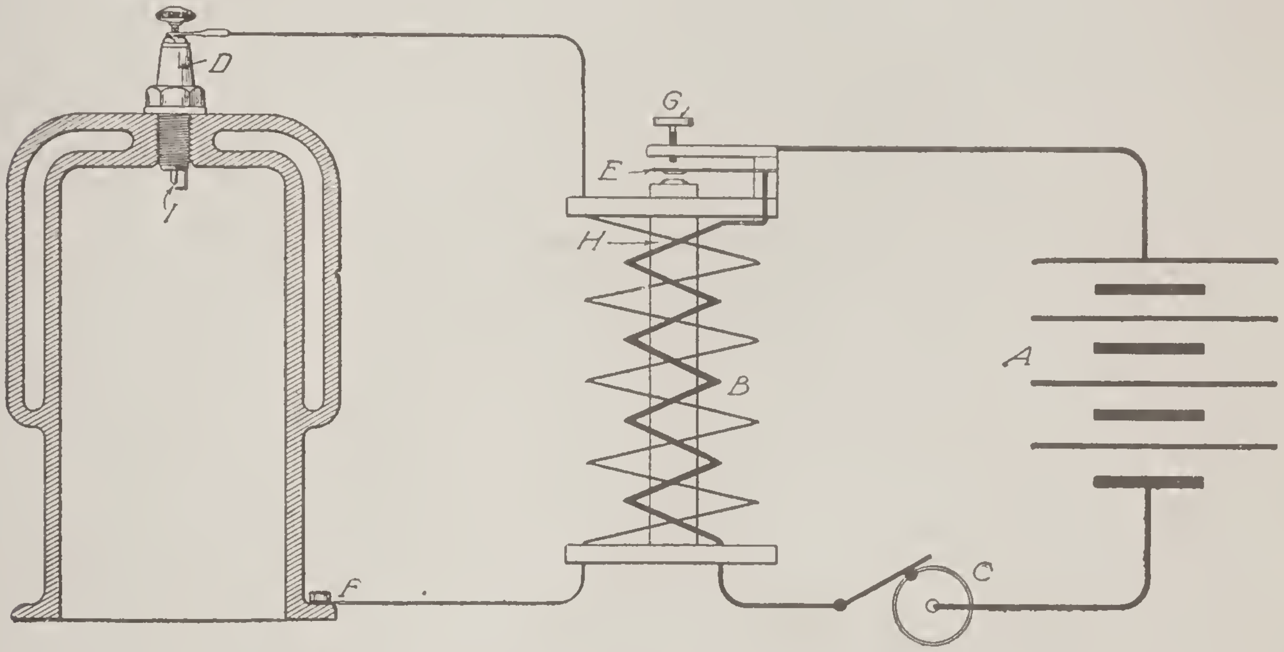


Fig. 42. Diagram of High-Tension Ignition System

With a system of the type described, when contact is made the first result is attraction of the vibrator blade *E* by the magnetized core *H* of the coil. This, by drawing *E* away from the contact screw *G*, at once breaks the primary circuit again, and this demagnetizes *H*, with the result that *E* again springs into contact with *G*. The effect of this is to cause a rapid series of current surges through the coil *B*, as long as the contact maker *C* maintains the contact.

Each time a surge of primary current passes through a coil, a secondary current of very high voltage is induced in the secondary circuit, which is grounded on the cylinder at *F* and connected at *B* with the spark plug. This plug, for high-tension ignition, has an open gap of about $\frac{1}{32}$ inch at *I*, across the resistance of which gap the current will jump, because of its high tension. Ignition is thus effected by a rapid succession of sparks across *I*.

This briefly describes what may be termed the rudiments of a high-tension ignition system and the diagram shows their relation to one another. Of course, this simply has reference to a single-cylinder motor. For each extra cylinder in an ignition system of the type illustrated, there is another contact point on the timer and another coil. The timer or contact maker is sometimes referred to as an interrupter, though this is not technically correct as its function is first to close the circuit.

SOURCES OF CURRENT

Up to about 1905, batteries were universally relied upon in this country for ignition work, the only exceptions to this being a few high-priced imported cars, some of which had magnetos operating low-tension systems with the so-called make-and-break spark plugs, while one or two, notably the Panhard, was equipped with the Eisemann magneto, designed to operate a non-vibrator coil. The writer imported the second of these magnetos to be brought into this country in the latter part of 1902, but the principles of its operation were so little understood, despite the fact that the magneto had been used in hand-ringing telephones for a generation, that automobile designers were frankly skeptical regarding it, and only the few electrical men then in the industry had the slightest conception of its possibilities. In fact, Mr. J. M. Packard, then head of the Packard Company, was the first man out of dozens to whom it was shown to realize what the magneto meant to automobile ignition.

CHEMICAL SOURCES OF CURRENT

Primary Batteries. In the face of the advent of the magneto (1902), the majority of American designers preferred to stick to the battery, usually the dry cell. The term dry cell is really a misnomer, since a cell of this type consists simply of a zinc element constituting the case of the cell, a carbon element centered within this, and an electrolyte composed of a moist paste of suitable chemicals. The top of the cell is commonly sealed with pitch or wax compound to prevent the moisture from evaporating, and if by any chance the cell does become really "dry", its usefulness is then at an end.

Defects of Dry Cells. The chief defect of the dry cell is that it is an "open-circuit" battery, that is, the circuit is normally open and when closed for a brief period the cell will produce a heavy cur-

rent, at a low voltage, i.e., $1\frac{1}{2}$ volts on the average. But to enable it to do so, the time of contact must be brief and the periods of rest frequent. Otherwise, the cell becomes "polarized". The hydrogen generated as the zinc element passes to the carbon element in such volume as to completely cover and insulate it from the active material of the cell, consisting of a solution of sal-ammoniac and water. The use of a depolarizer, usually manganese dioxide, prevents this to a certain extent, but not sufficiently to avoid having the current output of the cell fall off very rapidly if the contact exceeds a few seconds. But as soon as the circuit is broken again, the hydrogen is rapidly dissipated and the cell is said to recuperate. It was the marvelous ability of the dry cell to recuperate rapidly after having been run down to a point where it no longer produced sufficient current to pass a spark at the plug, that led to so much dissatisfaction and to such a misunderstanding of the gasoline engine in the earlier days. With the extremely wasteful contact makers then used, a set of cells would run an engine satisfactorily for an hour or so, then it would begin to miss firing badly and soon stop. Inspection would reveal no sign of current. If a new battery were installed, the engine would again run satisfactorily, and the motorist usually decided that the old cells were "dead". If, however, the inspection consumed ten or fifteen minutes, the battery recuperated and upon being cranked the engine again ran, only to repeat the performance a short time later.

Liquid Batteries. The dry cell is, of course, one form of primary battery, this term being used to distinguish it from other forms in which the exciting chemicals are in liquid solution. Few attempts have been made to employ the latter type of battery for automobile ignition, due to the violent agitation of the liquid which would necessarily ensue from the vibration and jolting. The Edison-Lalande cell and a few others of similar character, in which the charging chemicals were supplied in convenient units ready for quick replenishing when the battery "died", were tried in isolated instances but never met with general application, except on the motor boat, where the Edison-Lalande cells have been widely used.

Storage Cells. The construction and advantages of the storage cell as well as its operation and handling are detailed at length in the section on "Electric Vehicles". Due to its ability to provide a

very much greater supply of current, it soon displaced the dry cell on all except the then lower-priced cars. While it represented a great improvement, the wastefulness of the contact maker and of the coil vibrators proved too much of a drain on even the storage battery, and it was accordingly displaced by the magneto. Since the general adoption of the latter, batteries have been wholly discarded except as a source of starting current, for the magneto does not generate sufficient current at a low speed to make it possible to start the motor without "spinning" it, which calls for considerable manual effort. Magneto practice is given in a succeeding section.

VOLTAGE AND SPARK CONTROL DEVICES

Changes in Ignition Methods. Up to a few years ago, it was generally considered that the magneto practically represented the

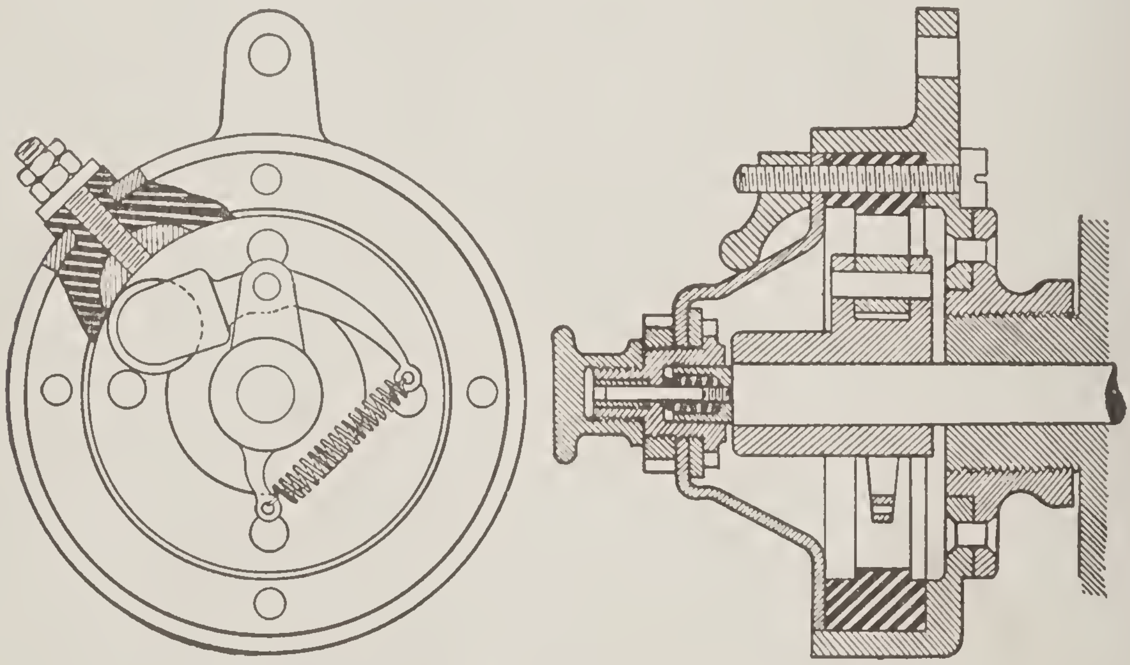


Fig. 43. Roller Contact Timer (*Horseless Age*)

ultimate type of ignition current generator and that batteries would never play anything but a secondary rôle. Small direct-current dynamos had been tried in a number of instances, chiefly prior to the advent of the magneto, but they were not then sufficiently developed for this form of service and proved quite as unreliable as the dry cell. The magneto was entirely dependable, made possible much greater speeds, and had few shortcomings, none of which were of a serious nature, so that its position was deemed impregnable. This was prior to the successful development of electric-lighting dynamos on the automobile, and more particularly the combined lighting and starting systems which are now in such general use.

The latter, in conjunction with improved forms of contact makers, has been responsible for bringing about a reversion to former practice with improved equipment.

Contact Makers or Timers. *Roller Contact Timer.* It was largely due to the crudity of the timing device that so much difficulty was experienced with early ignition systems. As the term indicates, the timer closed the circuit through the coil at exactly the moment necessary to produce the spark in the cylinder ready to fire. But the long wiping or rolling contact usually employed was so wasteful of current that it quickly exhausted even a storage battery. Fig. 43 shows a roller contact timer. The coil vibrators were another serious source of loss.

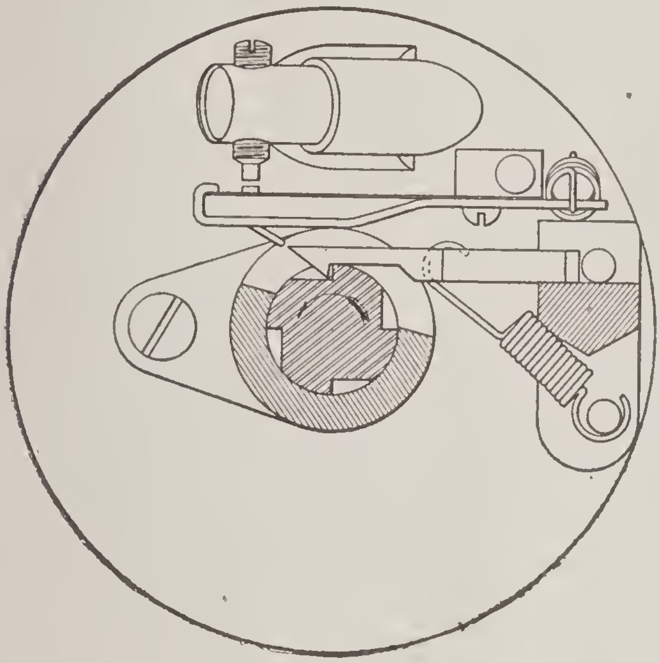


Fig. 44. Atwater-Kent Interrupter
Atwater-Kent Manufacturing Works, Philadelphia, Pennsylvania

Atwater-Kent Interrupter. The difficulties with roller contact led to the adoption of a totally different principle embodied in the Atwater-Kent interrupter, Fig. 44. This affords an exceedingly brief contact with an abruptness of the making and breaking of the circuit that is not secured with any other device. The effect is to produce a strong current surge and a heavy spark, but of the briefest possible duration.

The advantage of the brief duration is that great current economy is realized. The fact that only one spark is required for each ignition is an important contributing element to this economy.

With the Atwater-Kent interrupter, embodied in a distributor termed the "Unisparker", it is possible to run a car much further on a set of dry cells than could formerly be done with a storage battery, two to three thousand miles on four or five dry cells being nothing uncommon. This has led to the development of other devices along similar lines, and, with the unfailing source of current now provided by the lighting dynamo and the storage battery which forms part of the system, battery ignition has been raised to a level where it is now almost the equal of the magneto. But before

making further mention of that phase of the subject, it is necessary to refer to the coil in order to give a clear understanding of the matter.

Coils and Vibrators. *Function of the Coil.* Mention has already been made of the function of the induction coil or transformer in stepping up the voltage of the current in order that it may bridge the gap in the spark plug. A coil is also employed in connection with a low-tension system, but it is simply a single winding on an iron core which intensifies the current by what is known as self-induction. Though it raises the voltage by what may be termed the accumulation and sudden release of electrical energy acting in conjunction with a magnetized core, due to the sudden making and breaking of the circuit, it is not an induction coil as that term is ordinarily employed.

As shown by Fig. 42, the latter has two distinct windings, one of a few turns of comparatively coarse wire and the other of many thousand feet of exceedingly fine wire, with high-grade silk insulation. After completing the coil, consisting of two superimposed windings and an iron-wire core passing through their center, it is placed in a wood box which is filled with melted paraffine wax which, upon solidifying, greatly enhances the resisting power of the insulation to breakdown, due to the great difference in potential between various parts of the secondary winding. To set up an induced current in the secondary winding, the primary circuit must be quickly opened and closed.

Necessity for Vibrator. The breaking of the primary circuit is accomplished by the use of a vibrator, a typical form of which is illustrated at *E*, *G*, and *H*, Fig. 42. This consists simply of the thin blade of spring steel at *E*, provided with an armature at the free end to intensify the attraction of the coil *H*, and adjacent to the adjusting screw at *G*, by which the distances between the contact points can be accurately set. In addition to these elements it is usual to provide a screw adjustment for increasing or reducing the tension of the vibrator blades.

Contacts in the best vibrators are made of platinum, or, better still, of platinum-iridium alloys, which are very hard as well as extremely resistant to the very high, though brief and localized, temperatures of the small arcs that form across the terminals each time the contacts are separated. In cheaper coils, German silver, silver,

and other metals often are much used for contact points, but the only advantage of these over platinum or platinum alloys is their lower price.

Complication of Multi-Vibrator. A vibrator coil is necessary for each cylinder, each coil being energized as the timer passes over the contact corresponding to it, thus putting it in connection with the battery at the moment that particular cylinder is to fire. Fig. 45 shows a four-unit coil, i.e., for a four-cylinder motor. However, the coil cannot act before its core becomes "saturated", that is, thoroughly magnetized, and it must then pull its armature down against the tension of its spring, so that there is both an electrical and a mechanical lag, or, in other words, an appreciable amount of time elapses between the moment the circuit is closed by the timer and that at which it is again broken by the vibrator to cause the spark in the cylinder. A delicate adjustment is most sensitive and minimizes the lag besides economizing on current, but it is difficult to maintain. A stiff adjustment, on the other hand, will remain operative for a longer time, but its greater inertia makes the motor sluggish in action while the current consumption is increased several times over. Despite the use of platinum contact points, the heat of the spark is such that the latter burn away rapidly, necessitating frequent adjustment. As it is next to impossible to adjust four or six vibrators so that they will operate uniformly, it will be apparent why the vibrator coil was given up as soon as the magneto demonstrated that it was not a mystery beyond the understanding of the average motorist. The vibrator coil is accordingly obsolete and but for the fact that its existence has been extended by the Ford, it would probably be unknown to the majority of present-day motorists.

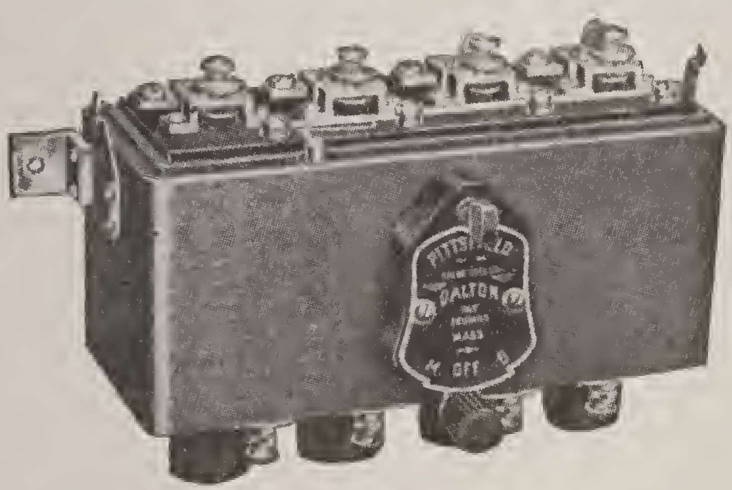


Fig. 45. Pittsfield Multi-Vibrator Coil
Courtesy of Pittsfield Spark Coil Company, Dalton, Massachusetts

Master Vibrator. To overcome the shortcomings of the four-unit vibrator coil, it is necessary to add a fifth coil. The latter is fitted with an especially sensitive and well-made vibrator which

takes the place of the four vibrators on the original coils, so that the extra coil is termed a *master vibrator.* In operation, all four of the original vibrators are screwed down hard so as to make a permanent connection, and the fifth coil is connected in the primary circuit so that the action of its vibrator breaks the circuit in the

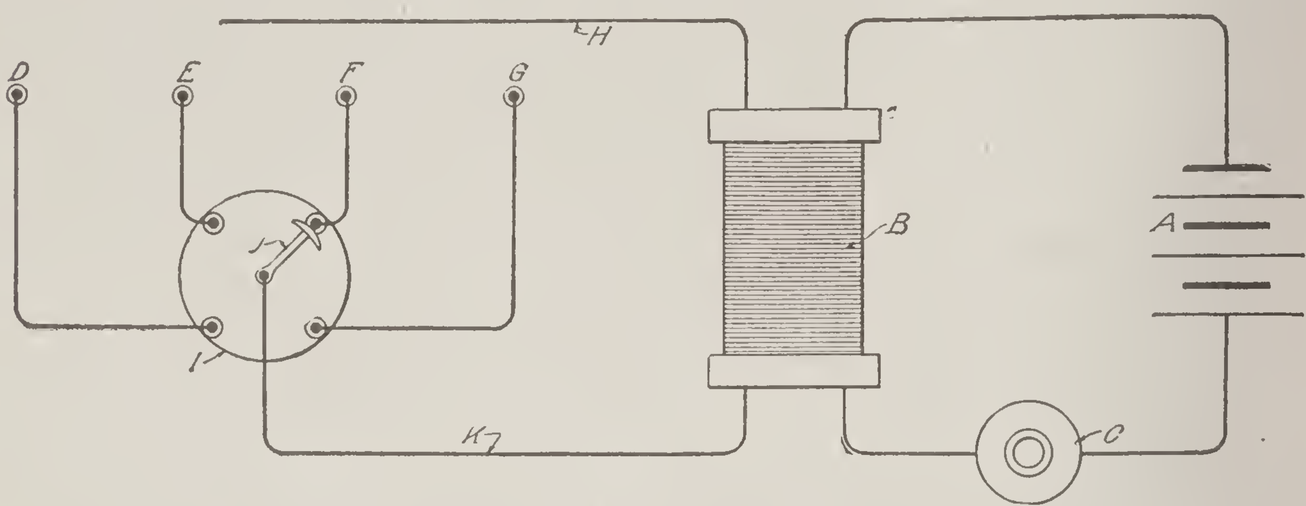


Fig. 46. Wiring Diagram of Non-Vibrator High-Tension System

primary of each one of the coils in turn. It is accordingly only necessary to adjust a single vibrator, and regardless of whether this adjustment be good or bad, it is uniform for all four cylinders so that they fire with the same timing. But at the best, the arrangement is only a makeshift as the vibrator coil long ago ceased to have any legitimate excuse of existence on the automobile.

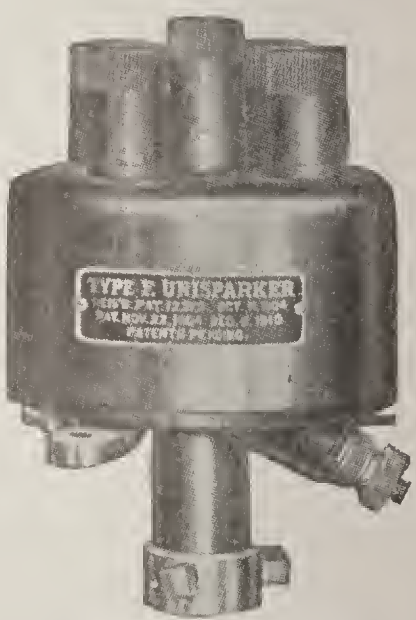


Fig. 47. Atwater-Kent Distributor

Non-Vibrator Coil. As the term indicates, this is simply an induction coil minus the vibrator. But instead of using four coils, as with the vibrator type, a single coil is employed, and a distributor is inserted in the secondary or high-tension circuit. The essentials of such a system are shown by Fig. 46, a battery being indicated as the source of current. The timer C is driven by the camshaft of the motor so that the battery circuit is successively closed and opened in the usual firing order of the cylinders, four contacts being made for each two revolutions of a four-cylinder four-cycle motor. The contact is of sufficient duration to permit the coil to "build up", i.e., to have its soft iron core become thoroughly magnetized, and is then quickly broken. At the instant that the latter occurs, the finger J of the distributor is passing the contact of the

cylinder F to be fired. The timer and distributor must accordingly be driven synchronously, so that the contacts in both occur simultaneously. This is accomplished by combining them in a single unit, as shown in Fig. 47, illustrating the Atwater-Kent "Unisparker", or as in the various types of magnetos illustrated further along.

Limitations of current supply having been overcome by the adoption of the magneto or the storage battery kept charged by the lighting dynamo, non-vibrator coils are usually wound to a higher resistance than the old vibrator coils, so as to produce a current of higher tension in the secondary. As this type of coil requires no adjustment, it is generally installed horizontally with its face flush with the dash, and on this face is mounted the switch giving three control points, i.e., neutral, battery (for starting), and magneto. The Remy dash coil, Fig. 48, is a typical example.

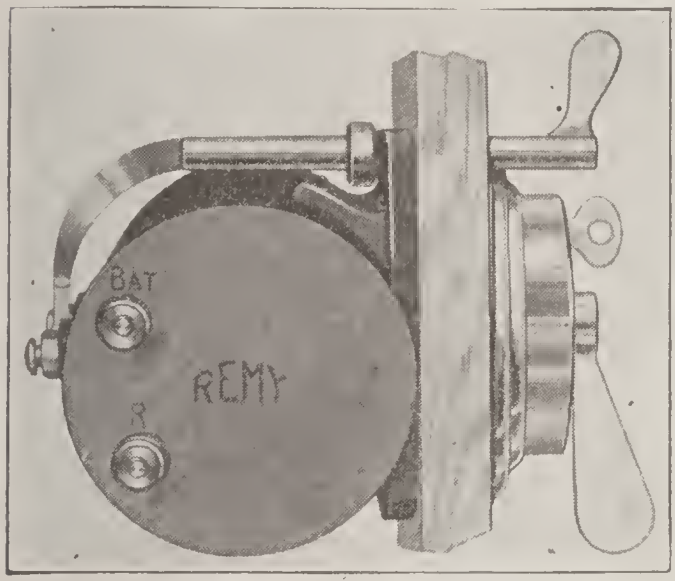


Fig. 48. Remy Single Non-Vibrator Coil Showing Method of Installation

Distributor. This is simply a modification of the timer, designed to handle the high-tension current, or to distribute it to the different plugs. It takes the place of the multi-unit coil in which an independent coil is employed for each cylinder. Owing to the high voltage of the secondary current, actual contact is not necessary in a distributor, a small gap or clearance presenting no obstruction to the passage of the high-tension current, so that wear at this point is avoided. In the earlier types, a brass arm passing close to contact points, or sectors embedded in hard rubber, was usual. Carbon brushes making contact against the disk by means of light springs, were subsequently adopted and are now commonly used. As the carbon is very hard and its contact surface becomes glazed by the friction, the wear is practically negligible. The complete wiring of a distributor system is shown in Fig. 46. H is the ground or common-return connection of the secondary circuit and K is the connection to the distributor I, from which the high-tension current is distributed by the arm J to the spark plug leads D, E, F, and G,

Condenser. The condenser is technically known as an electrical "capacity" in that it has the ability to absorb a quantity of electricity proportioned to the area of its conducting surfaces and to the nature of the dielectric employed. This property is utilized to absorb the excess current passing at the moment the primary circuit of the ignition system is opened by a vibrator, thus bringing about a quick cessation of the current flow and preventing the destructive arcing or burning that would otherwise occur at the contact points. The charge thus absorbed is immediately returned to the circuit in the form of a discharge, when the points come together again and a higher potential value is impressed upon the current. A condenser consists of conducting surfaces placed between insulating surfaces, known as the dielectric. For ignition work, the conducting surfaces are sheets of thin tinfoil cut with conducting tabs which project beyond the ends of sheets of paraffined paper on which the tinfoil is placed. Between each two sheets of paraffined paper is placed a sheet of tinfoil, the latter being arranged so that the tabs project at alternate ends, Fig. 49. The paraffined paper overlaps the tinfoil all around to the extent of an inch or more to prevent a discharge over the edges of the sheets. The capacity of the condenser depends upon the number and the size of the sheets of tinfoil and the thinness and the character of the dielectric separating them; and, when a sufficient number have been assembled, the projecting tabs at each end are riveted or clamped together and a flexible wire lead connected to each. It is then connected in multiple with the vibrator, and, in the case of a coil is inserted in the containing case of the latter and further insulated as well as held in place by having molten paraffine poured around it so as to fill the space. A condenser practically eliminates sparking at the contact points and is also used with the contact breaker of a magneto.

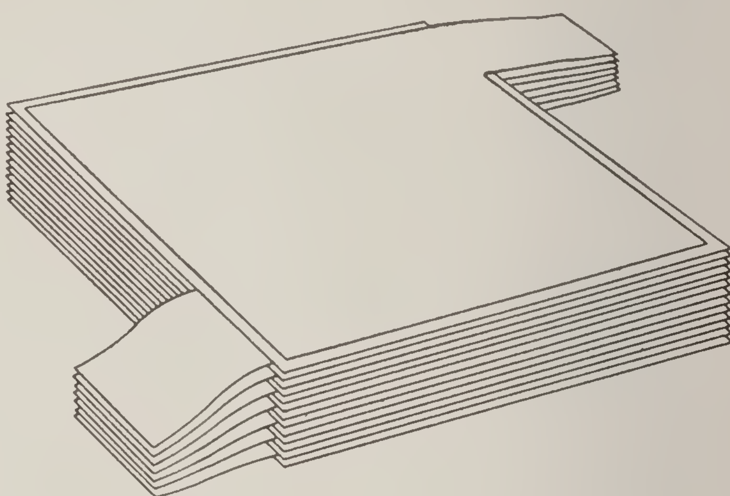


Fig. 49. Sketch of Condenser

Spark Plugs. No small part of the trouble experienced with early ignition systems was due to the defective design of the spark

plugs employed. Where an over-rich mixture is delivered by the carbureter, i.e., one containing too much gasoline in proportion to the air, a certain amount of the carbon is unburned and remains in the

Fig. 50. J-D Spark Plug

Fig. 51. V-Ray Spark Plug

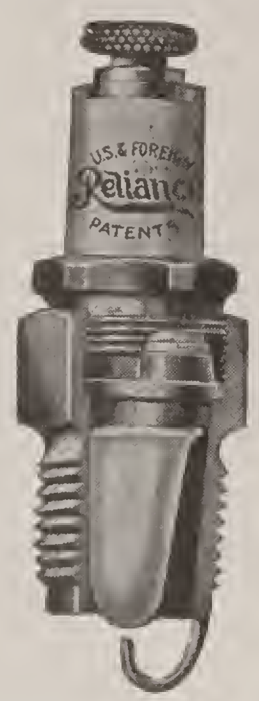


Fig. 52. Open-Point Spark Plug

cylinder in the form of soot. This is greatly increased by an excess of lubricating oil finding its way into the combustion chamber. The heavier carbons of this burn to the same consistency and are also deposited on the piston head, cylinder walls, valves, and other exposed surfaces in the form of a flint-hard coating. The end of the spark plug receives its share and, as the carbon is an excellent conductor, the plug is accordingly short-circuited, so that the current, instead of jumping the gap between the points, takes a path of lower resistance across the carbon-coated insulating surfaces.

Fig. 53. Multi-Point Spark Plug

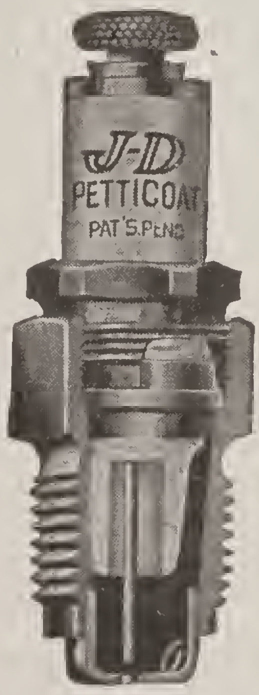


Fig. 54. Chambered-End Spark Plug

Fundamental Requisite. The spark plug is the "business end" of the ignition system and no matter how elaborate or efficient the essentials of the latter may be, its successful operation is governed entirely by that of the plug. As originally designed, the insulating material filled the shell at the sparking end, affording a direct path

for the current as soon as this small surface became covered with carbon. Failure was accordingly frequent, it being nothing unusual to have to clean such a plug in less than fifty miles of running. To overcome this, a recess was allowed between the insulation of the central electrode and the outer shell. This simple expedient constitutes a basic patent (Canfield) under which all spark plugs are manufactured. Porcelain, mica, or artificial stone is used as the insulating material, the first-named being most generally employed. This is made in various forms, as shown by the sections, Figs. 50 and 51, and it will be noted that the smaller diameter of the insulated

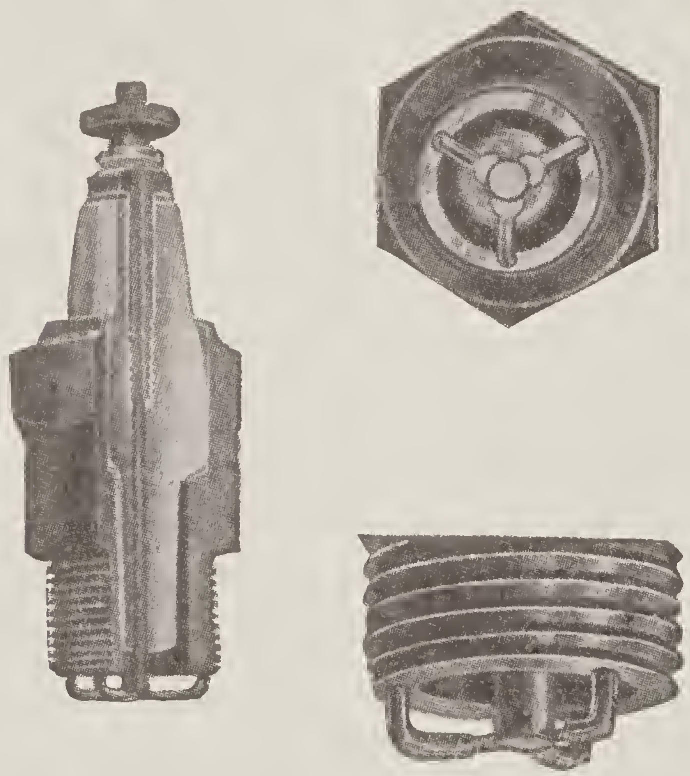


Fig. 55. Bosch High-Tension Spark Plug

electrode in the center greatly increases the area of the surface of both shell and porcelain that must be coated with carbon before a path is formed for the current.

Electrode Arrangement. Practice also varies considerably in the arrangement of the electrodes, taking the form of open points as in Fig. 52, a bridge as in Fig. 50, or a number of points as shown in Figs. 51 and 53. In some instances, the central electrode is enclosed in a chamber, the gas entering through a small hole in the shell, as shown in Fig. 54. Considerable advantage is claimed for the type of plug having a plurality of gaps, the number usually being three, as shown in Fig. 55, or four as in Fig. 53. It is more theoretical than actual, however, as the current always takes the shortest path and the

bridging of any one of the gaps by a particle of conducting material, such as carbon, short-circuits all of them.

Series Plugs. As shown in the various wiring diagrams, the shell of the plug is one of the electrodes and forms a part of the circuit by being screwed into the cylinder, the latter constituting part of the common ground return for both the primary and the secondary circuits of all ignition systems. Experiment has shown a slightly increased power resulting from the simultaneous occurrence of two sparks in different parts of the combustion chamber of the cylinder, especially with the T-head type of cylinder in which the two plugs can be located in the oppositely placed valve ports. This is termed double-spark ignition and the type of magneto designed for this purpose is described in the section on "Magnetos". To obtain the same result with the standard ignition circuit designed to produce but one spark in each cylinder, what is known as a "series" type of plug has been developed. One of these is shown in Fig. 56. In this the spark occurs between two central electrodes, as shown, the shell not forming a connection with the cylinder. The lead from the distributor is attached to one of the binding posts of this plug and a second wire connected to the other binding post is led to a standard type of plug, thus completing the circuit and placing both plugs in series so that a spark occurs simultaneously in both. By means of an attachment as shown in Fig. 57, this type of plug can be used with a grounded return, the arm shown connecting the shell in the circuit. As the majority of motors now in use have L-head cylinders, and even at the best the advantage gained is very slight, the use of series plugs has not a great deal to recommend it.

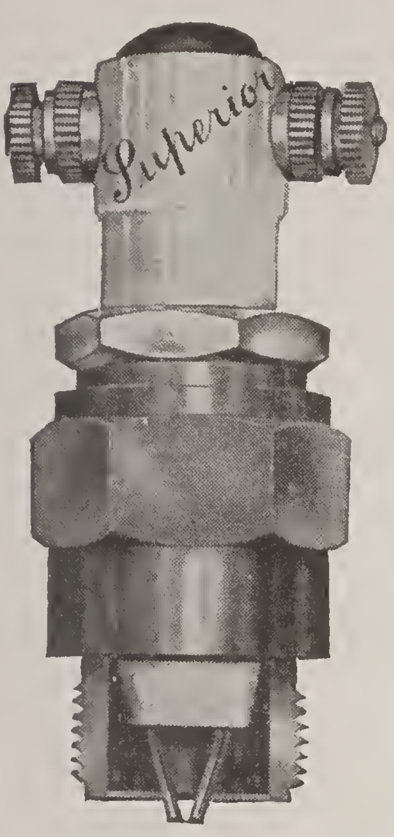


Fig. 56. Series-Type Spark Plug

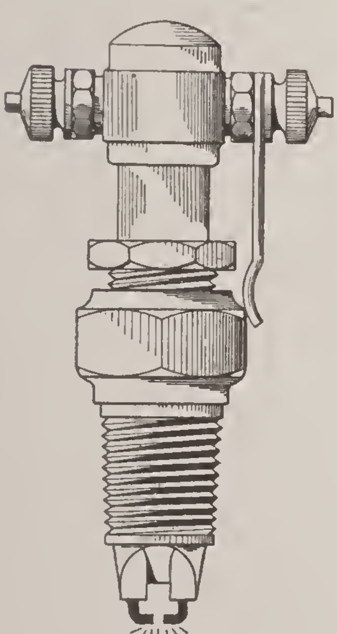


Fig. 57. Method of Converting Series Plug

Magnetic Plugs. With a view to overcoming the defects of the mechanically operated make-and-break plug as used on low-

tension ignition systems, an automatic plug was developed. As shown by the section, Fig. 58, this is simply a solenoid A and plunger C, the latter being held in contact at D by a spring B. The current passing through the winding A lifts the plunger and the spark occurs at D. The remainder of the system consists of a low-tension magneto or other source of current supply and a timer. Such plugs have been used to some extent on stationary engines, but have not proved practical on the automobile motor, as the high temperatures drew the temper of the plunger spring and often burned out the insulation of the winding.

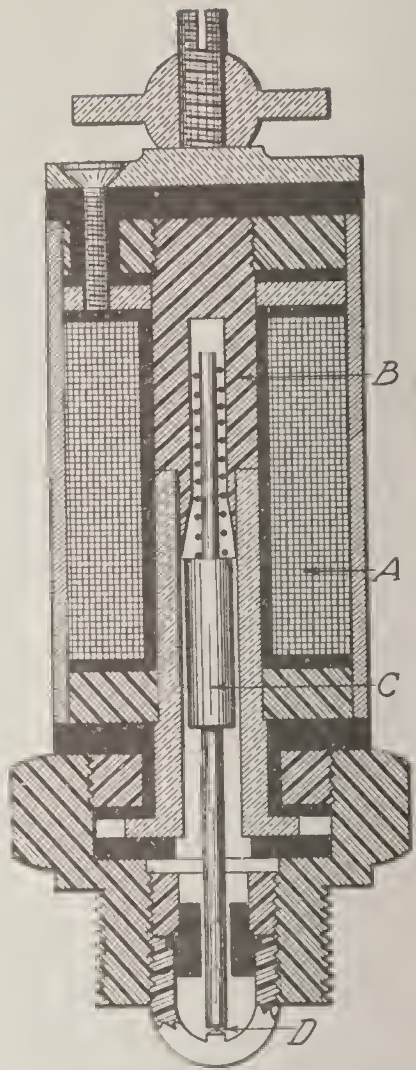


Fig. 58. Low-Tension Magnetic Spark Plug

Priming Plugs. For low-priced motors, such as the Ford, which have no pet cocks or compression-release cocks on the cylinders, a spark plug combined with a pet cock, such as that shown in Fig. 59, can be had. These are usually known as "priming" plugs in that they permit of priming the cylinder with gasoline to render starting easy in cold weather.

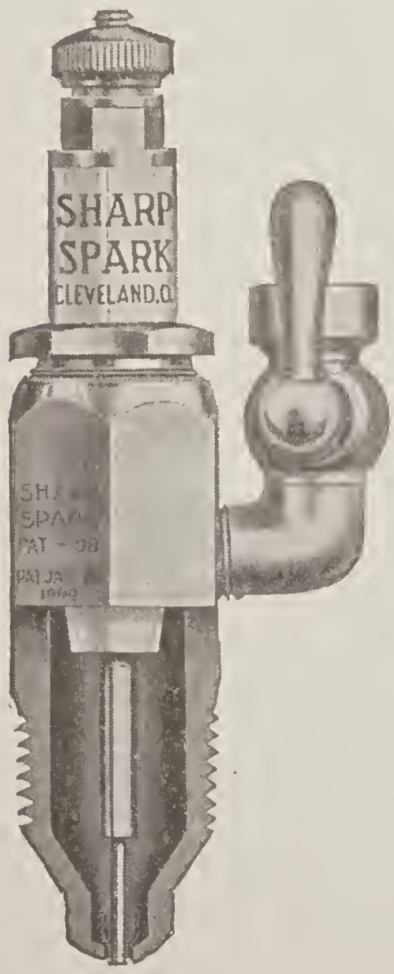


Fig. 59. Priming Type Spark Plug

Waterproof Plugs. Ignition systems, on motor-boat engines in particular, are apt to suffer short-circuiting from spray or dampness, though this often happens on the automobile as well in heavy rainstorms. To guard against this a so-called waterproof type of plug is provided. The precaution usually takes the form of a hood of hard rubber or other insulating material placed over the connection, as shown in Fig. 60.

Plug Threads. European practice has standardized a straight-threaded plug, the thread itself usually being of fine pitch. A plug of this kind is screwed home on a gasket

of copper and asbestos or of the latter material alone, which is relied upon to prevent leakage. Foreign types are usually referred to as "metric" plugs, as the thread dimensions are based on the metric standard. As developed at first in this country, all spark plugs were made with an "iron-pipe" thread. This has a taper of three-fourths inch to the foot and the plug is screwed into the cylinder as far as the taper will permit, no other provision being made to hold the compression. As this is a crude expedient, adopted chiefly because of its cheapness, and the metric standard is not employed here, an S.A.E. standard plug has been developed along the same lines, both the plug diameter and the thread itself being made somewhat larger than those used abroad.

Fig. 60. Spark Plug, with Waterproof Connections

Hydraulic Analogy in an Ignition System. A comparison of the workings of an ignition system with the action of an hydraulic system having similarly related parts will serve to make clear the operation of the former. It must first be borne in mind that a high-tension ignition system consists of a source of current; an interrupter, or method of automatically breaking the circuit of this current supply, timed with relation to the revolution of the engine crankshaft; a condenser to suppress the arc at the interrupter contacts; a transforming device, or induction coil, to transform a current of comparatively high amperage at a low potential to one of high voltage; a device for distributing this high-tension current to the spark plugs, also timed with relation to the crankshaft; and the spark plugs themselves.

Current. The electric current in the ignition system may be represented by water flowing in a pipe from a source of supply which puts it under pressure, corresponding to the storage battery. A certain amount of frictional resistance must be overcome by the water in flowing through the pipe and this is equivalent to the electrical resistance of the wiring in the ignition circuit. The rate of water flow in the pipe corresponds to the current in the coil, and the inertia of the water to the inductance of the primary winding of

the induction coil. Now, if the flow of water be suddenly stopped, there will be an enormous increase in the pressure, due to the inertia of the water. This effect, known as *water hammer*, is commonly noticed in the larger sizes of pipes carrying water under considerable pressure. It corresponds to the great increase in the pressure, or voltage, which takes place when the flow of current in the primary of the ignition circuit is opened suddenly by the interrupter. This is due to the inductance in the coil. A quick-closing valve in the water system would accordingly correspond to the timer contacts which interrupt the current in the primary of the induction coil.

Office of Condenser. There is one peculiar tendency of timer contacts which must be mentioned here to make the analogy more complete. Unless protected by a condenser, they are apt to burn away very rapidly, due to the arc produced by the current at the moment of separation. (This is also true of the contacts of the battery cut-out and of the regulator employed in connection with starting and lighting systems; the condenser does not eliminate this tendency to burn away but reduces it to a minimum.) This failing on the part of the timer contacts would correspond in the hydraulic system to a valve with a very thin edge which would be liable to bend under the sudden rise in pressure before it is fully closed. In the case of both systems, therefore, it is necessary to arrange for some protection, and a condenser is supplied for this purpose in the ignition system.

In the hydraulic system, it takes the form of a surge chamber, as shown in Fig. 61. This chamber has an elastic diaphragm centrally placed in it, and the chamber itself is shunted, or connected, around the valve in the same manner as the condenser is connected to the contact points. When the valve begins to close, this surge chamber relieves the pressure to some extent during the operation of closing the valve and so protects the thin edge of the valve from bending. After the valve is fully closed, there is, of course, no further danger of its being bent over. In the electrical system, the condenser supplies similar protection, reducing the voltage at the timer contacts at the moment of separation and keeping this voltage reduced until they are fully open, thus preventing the current from bridging the gap, or *arcing*. Once the contacts are fully separated, the low-tension current cannot jump the air gap, so that there is no further danger of their burning.

Transformer. In order to utilize the pressure produced by the sudden closing of the valve, it is necessary to provide some transforming device, such as a pressure chamber. This is illustrated in Fig. 61, and it will be noted that it is of a much larger diameter than the pipe. As the pressure in the chamber and the pressure in the pipe will both have some unit value (measured in pounds per square inch), the total pressure on the piston will be to the pressure in the pipe as the area of the piston is to the area of the pipe. By the use of a pressure chamber of large diameter, compared to that of the pipe, a very considerable force is applied to the piston, but the

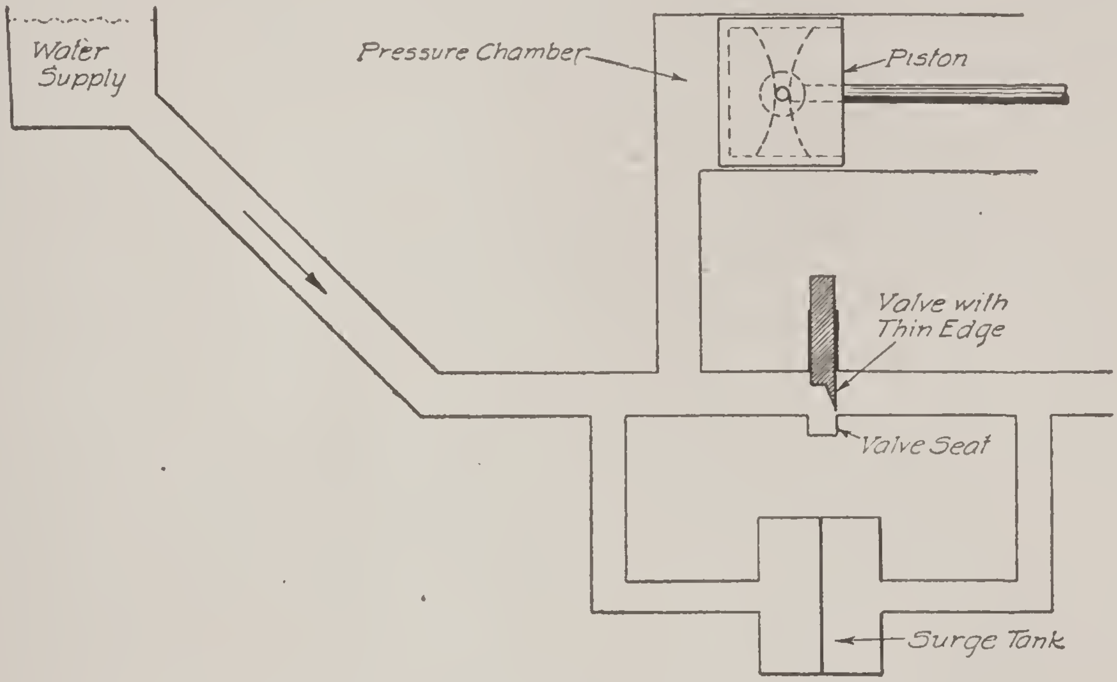


Fig. 61. Diagram Showing Hydraulic Analogy of Ignition System

distance it will travel is very slight. (To simplify matters, the weight of the piston is disregarded in this connection.)

It is likewise necessary to provide a transforming device in the ignition system, and, in the case of both magneto and modern battery systems, this is the induction coil, having a relatively large number of turns in the secondary winding and a comparatively small number of turns in the primary. (In the earlier battery system, a vibrating coil is used for each cylinder and there is no distributor, while in the true high-tension magneto, the coil is part of the armature winding.) Just as in the hydraulic system the increased area of the piston is responsible for the increased total pressure on it, so the large number of turns in the secondary of the coil give the very high voltage required to enable the current to bridge the air gap at the spark plugs.

This high voltage is accompanied by a very small amount of current, just as in the hydraulic system the greatly increased pressure on the piston produces but a very slight movement of the latter.

INDUCTION SOURCES OF IGNITION CURRENT—MAGNETOS

Owing to the failure of either dry cells or storage batteries to supply sufficient current to operate the wasteful contact devices at first employed, mechanically driven current generators were adopted. American practice at first favored the small, high-speed direct-current dynamo, but as proper regulating devices had not then been developed, it was not successful, chiefly because its speed range was so limited. Few of these little dynamos generated sufficient current at less than 1200 r.p.m. to ignite the charge in the cylinder, so that at slow speeds they would not run the motor. If run much faster, they burned out and were accordingly abandoned.

Working Principle. The magneto is simply a small dynamo in which the fields consist of permanent magnets, instead of electromagnets, the cores of which only become magnetic when a current is passed through their windings. Hard steel, particularly when alloyed with tungsten, retains a very substantial percentage of its magnetism, after having been once magnetized by contact with a powerful electromagnet. Its retaining power is further increased by placing a "keeper", or armature, across the poles, or ends. The advantage of a permanent field for magneto use is that it is at its piston produces but a very slight movement of the latter. This rise in the voltage and decrease in the current can be made clear by a brief explanation. By the principles of induction, a current flowing in the primary coil will induce a current in the secondary coil. The energy of these currents in watts is equal to the electromotive force in volts times the current in amperes. Now, as the transformer cannot create electrical energy, the energy of the transformed current must equal the energy of the current before it is transformed, barring a small loss within the transformer. This means that if the voltage of the current is raised from 6 volts, say, in the primary to 6000 volts in the secondary, the amperage of the primary current must be correspondingly reduced from 2 amperes, say, to .002. In other words, the product of the current and electromotive force must be always the same before and after transformation.

maximum intensity regardless of how slowly the armature is revolving so that a good spark is produced at very low speeds; while its initial value cannot be exceeded no matter how fast the machine is run, so that the armature winding cannot be burned out. All magnetos generate an alternating current so that when used with a coil there is no necessity of frequently making and breaking the circuit, as is done by the vibrator of a coil handling direct current, the alternate surges of current from zero to maximum of opposite polarity producing the same effect more efficiently.

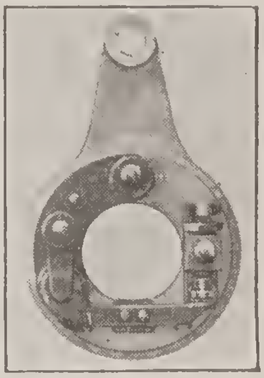


Fig. 62. Remy Magneto Contact Breaker

Low-Tension Magneto. A low-tension magneto is nothing more or less than the simple instrument which formed part of the thousands of telephones of the hand-ringing type still to be found in rural districts. Built with more powerful magnets and wound to give a greater current output at a lower voltage, it was employed in connection with low-tension ignition systems. A magneto of this type is illustrated by

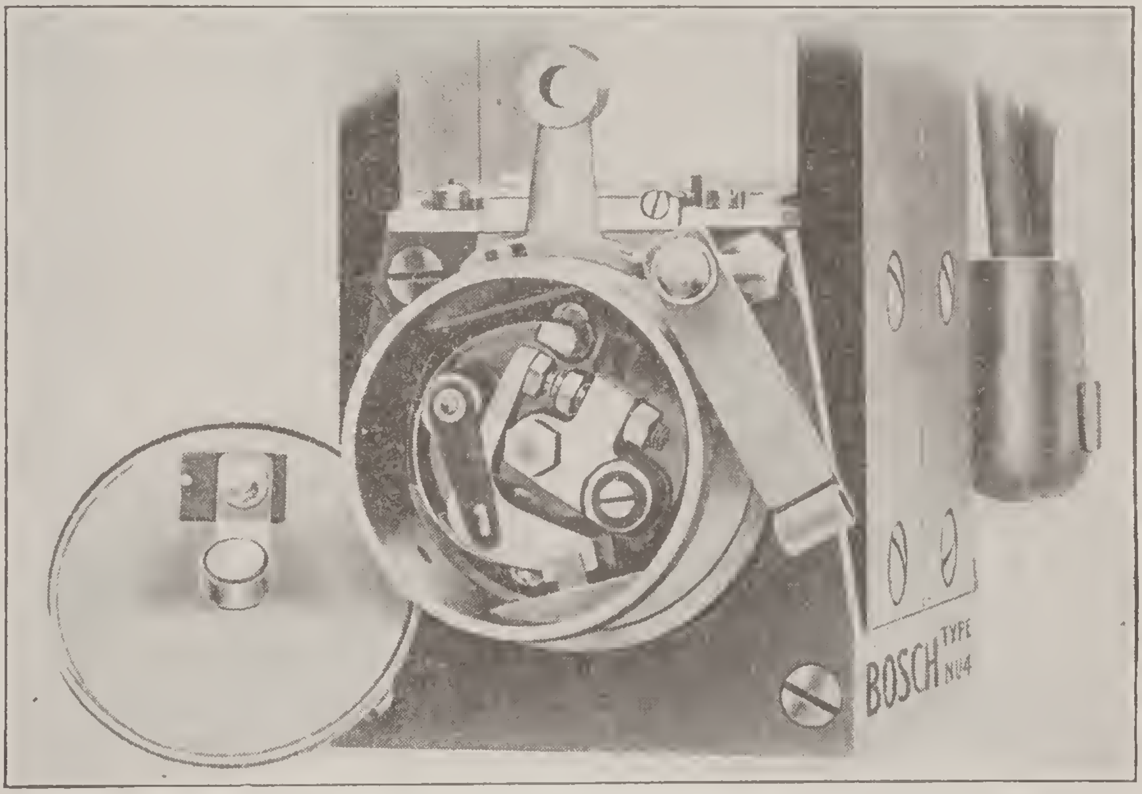


Fig. 63. Contact Breaker of High-Tension Magneto (Bosch)

Fig. 39. As the mechanically operated make-and-break plugs are timed, the magneto is simply revolved continuously without reference to the motor timing, the current being constantly delivered to the circuit through the usual collector ring and brushes. Magnetos

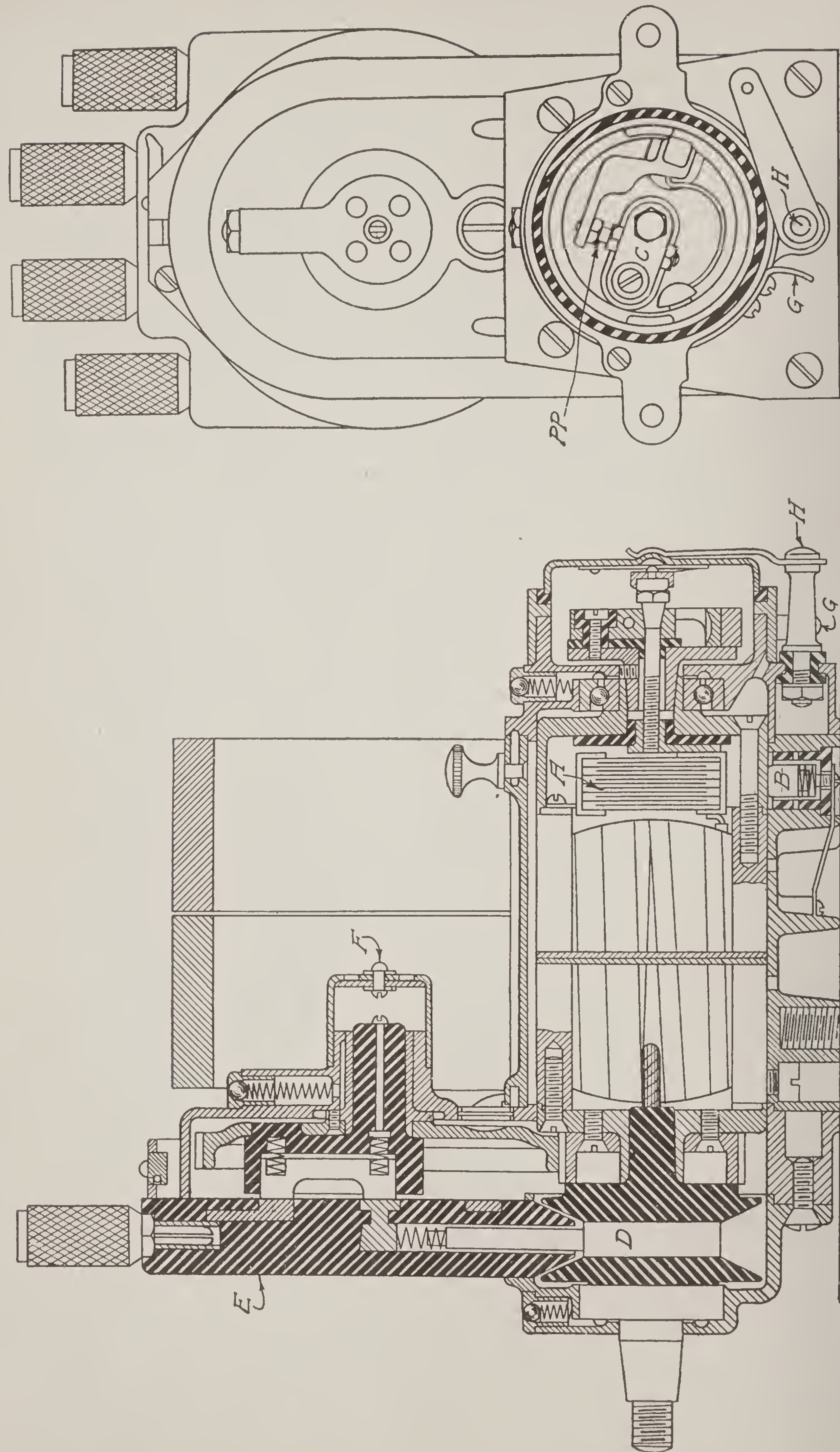


Fig. 64. Sectional and End Views Through High-Tension Magneto (*Horseless Age*)

of this type are still used to a greater or less extent on large, slow-speed stationary engines.

High-Tension Magneto. Essentially all magnetos are the same: that is, they have a permanent magnet field and a two-pole armature. In what may be best identified by terming it the *true high-tension type,* there are two windings on this armature, a primary winding of comparatively coarse wire in which the current is generated, and a secondary winding of fine wire, the same as an induction coil. A magneto of this type is timed with the motor according to the number of cylinders, being driven at crankshaft speed in the case of a four-cylinder motor and at one and a half times crankshaft speed in the case of a six. In addition to the usual current-collecting device, it is equipped with a contact breaker or interrupter, such as that shown in Fig. 62, which is part of a Remy magneto. Fig. 63 shows the same essential of a Bosch light-car type magneto. Except at the point in the revolution at which the spark is to occur in the cylinder, the armature circuit is normally short-circuited upon itself. This permits it to "build up", so to speak; that is, as the armature poles come within the most intense part of the field, the current in the armature winding reaches its maximum value and, at this moment, the contact points of the breaker are opened and a strong current is induced in the secondary winding. As the distributor runs synchronously with the contact breaker, the circuit to one of the plugs is closed at the same time the spark occurs at it.

Description of True High-Tension Type. A sectional view of a true high-tension magneto is shown in Fig. 64. In this the primary and the secondary windings on the shuttle armature are entirely separate to insure better insulation. These windings are not shown in section in the illustration, the usual insulating tape winding being indicated on the armature. Twice during every revolution of the armature, the primary circuit is opened at the platinum points $P P$ of the circuit breaker, the interruption occurring substantially at the moment when the primary current is at its maximum. From the primary winding, the current is conducted to the stationary member of the contact breaker C through the terminal B. A is the condenser. One terminal of the secondary winding is connected to the end of the primary winding, as in a coil, and the other connects with the high-tension collector ring D, from which it is conducted through a carbon

brush to the brush of the distributor above it for distribution to the four brass segments in the distributor plate *E*. These segments are connected to the four terminals shown extending above the magneto in the end view at the right and from them the usual high-tension cables are led to the plugs. The distributor is driven from the armature shaft of the magneto through 2 to 1 gearing so that it only makes one revolution for two turns of the crankshaft in the case of four-cylinder four-cycle motor, as in the latter but two explosions occur per revolution. To vary the time of occurrence of the spark in the cylinders, the contact breaker may be turned through part of a revolution by means of a rod and linkage fastened to one of the extensions of the contact breaker box, as shown in the end view. This connects with the spark timing lever on the steering wheel and, to stop the action of the magneto, it is only necessary to move this lever to the extreme retard position, which brings the spring *G* in contact with the bolt *H* and short-circuits the secondary winding.

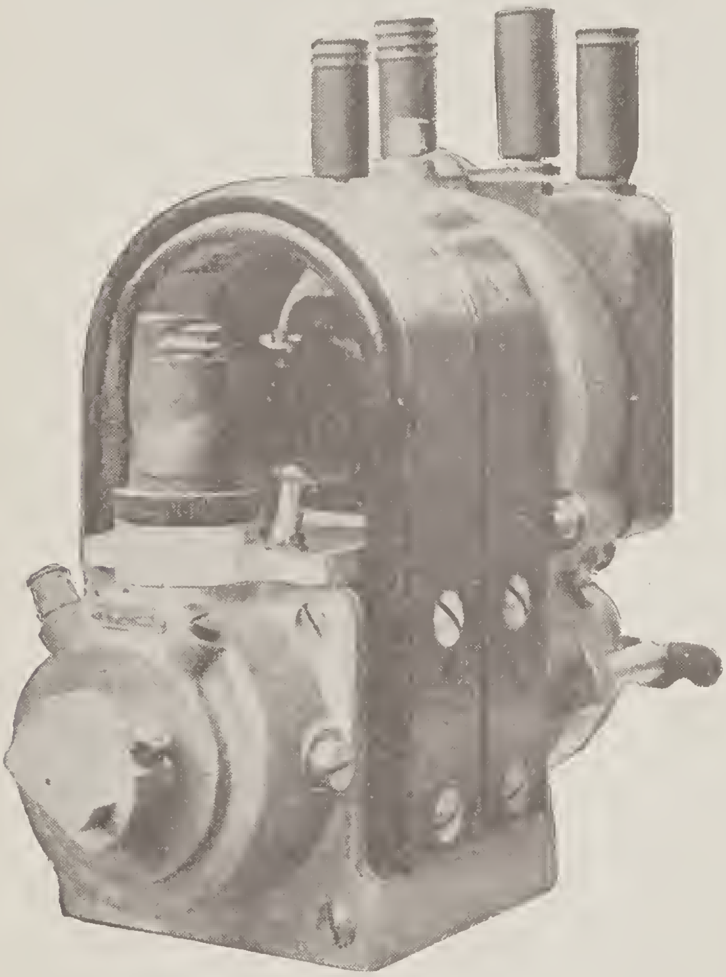


Fig. 65. Contact-Breaker End, Nilmelior Magneto

The magneto, Fig. 65, differs from the section, Fig. 63, chiefly in detail. The vertical plug just back of the contact-breaker box incorporates the safety gap.

Typical High-Tension Magneto Circuit. Fig. 66 is the wiring diagram for a high-tension system, using a true high-tension type magneto. *C* and *B* are the wires of the primary circuit, in which circuit there are also included, besides the current-generating coils of the armature, an induction coil built into the magneto, for raising the current tension, and a contact breaker *E*, which is carried on the same revolving spindle that bears the armature. The dotted lines indicate the ground return.

High-Tension Type with Coil. This is not actually a high-tension magneto, properly so-called, as it only generates a low-tension current, which is subsequently stepped up through a transformer or non-vibrator coil, but it is commonly so termed as it is always used in connection with a high-tension ignition system. In this case there is only a single winding on the armature and the current is led from the latter through the usual contact breaker and then to an independent coil, generally located on the dash. The condenser is combined with the coil, and from the latter the high-tension current is led back to the magneto to be distributed. Owing to its lower cost, this type of

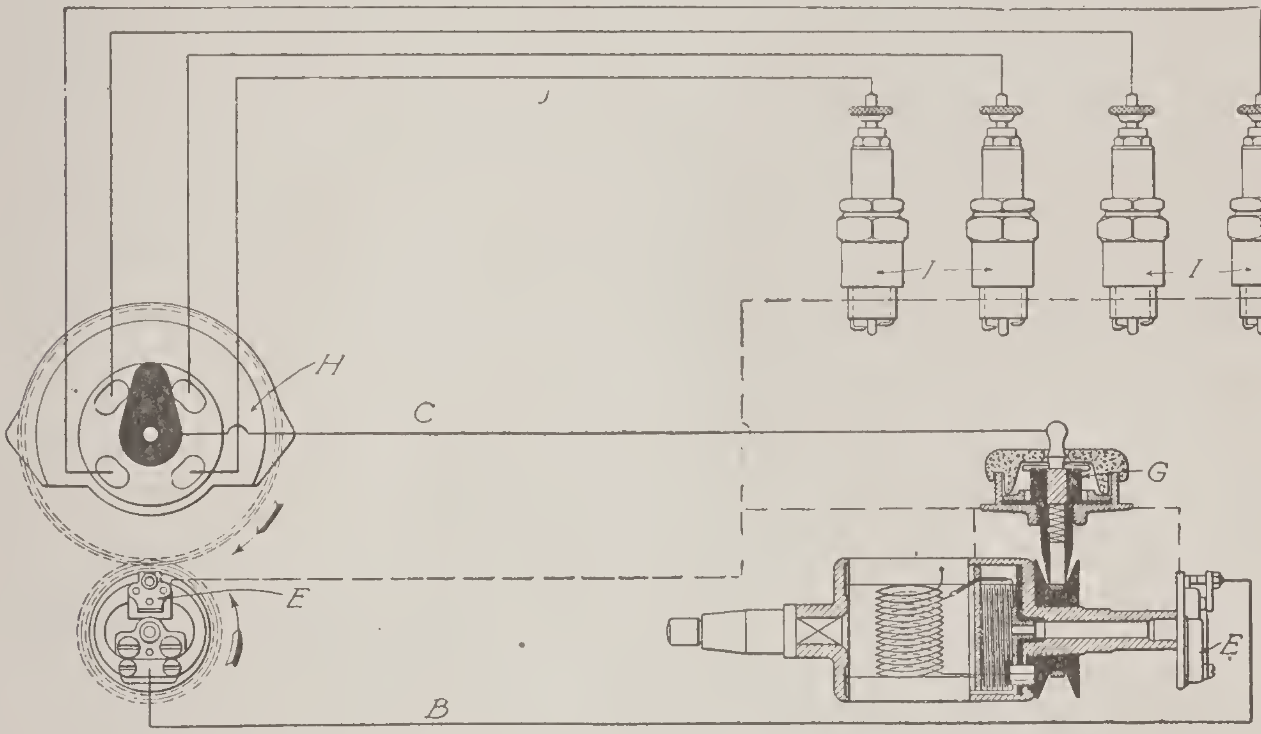


Fig. 66. Wiring Diagram of High-Tension Magneto System

magneto is probably more generally employed, especially on medium-priced American cars, than any other.

Safety Gap. If the current induced in the secondary winding of an induction coil meet with a resistance in the outer circuit in which the coil is connected, greater than the resistance presented by the insulation of its own windings, it will puncture this insulation and the expensive coil will be ruined. The placing of such a resistance in the high-tension circuit occurs when the connection of a spark plug is removed from the plug terminal and is allowed to dangle in the air beside the motor and, unless this were guarded against, it would result in the breakdown of the ignition system. The precaution takes the form of a safety gap. This is an opening inserted in the circuit, and its length is based on the safe maximum distance that the coil

can bridge in normally dry air. A safety gap of this kind is shown at F in Fig. 64. In the type of magneto just described above it is embodied in the coil. When an opening at any point in the high-tension circuit exceeds the length of this gap, the current takes the path thus provided, thus preventing the imposition of an excessive strain upon the insulation of the secondary windings.

Wiring Connections. For the actual operation of an induction coil, there is no necessity for any electrical connection between the primary and the secondary windings, the electrical energy being transferred from one to the other entirely by induction, i.e., through the intermediary of the magnetic lines of force which interlink both. However, for the sake of simplicity of external connections, the beginning of the secondary winding is usually connected to the end of the primary. Both the primary and the secondary circuits have a "ground return", which necessitates that one end of both the primary and the secondary winding of the coil be placed in positive metallic connection with the engine or car frame. By connecting the two windings, as mentioned, a single wire serves to ground both. The average coil, therefore, has only three terminals, i.e., one primary, one secondary, and one common ground connection.

On cars that are provided with magneto ignition alone, as is the case with French taxicabs and many other French light cars, there would be only two connections between the magneto and the coil, one primary and one secondary; one connection from the coil to a ground, as the motor or frame; and four connections direct from the magneto distributor to the spark plugs. This represents an ignition system reduced to its lowest terms of simplicity. As a matter of fact, it is even more simple in reality, as most French cars use the true high-tension type of magneto so that the four leads from the magneto to the plugs are the only external wires in evidence. Unless a magneto is in excellent condition, however—and the magnets lose their strength more or less rapidly under the influence of the heat and vibration—too much effort is required to start the motor. American manufacturers accordingly supply a battery for starting purposes, and on some of the high-priced cars this takes the form of an entirely independent battery ignition system, i.e., having a battery, coil, timer, distributor, and a separate set of spark plugs. It also constitutes an emergency system that may be resorted to in case of a

breakdown of the magneto, but the latter is so rare and the cost and complication of the extra system are such that the latter is not generally used. Instead, the magneto coil, contact breaker, and distributor are utilized with the battery as the source of current.

Inductor-Type Magneto. Mention has been made in the introductory of the fact that if a coil of wire be moved so as to cut the lines of force of a magnetic field, an e.m.f. will be induced in the wire. If, instead of moving the wire, a magnetic flux be made to pass through it first in one direction and then in the other, the same result will be obtained, i.e., an alternating e.m.f. will be produced,

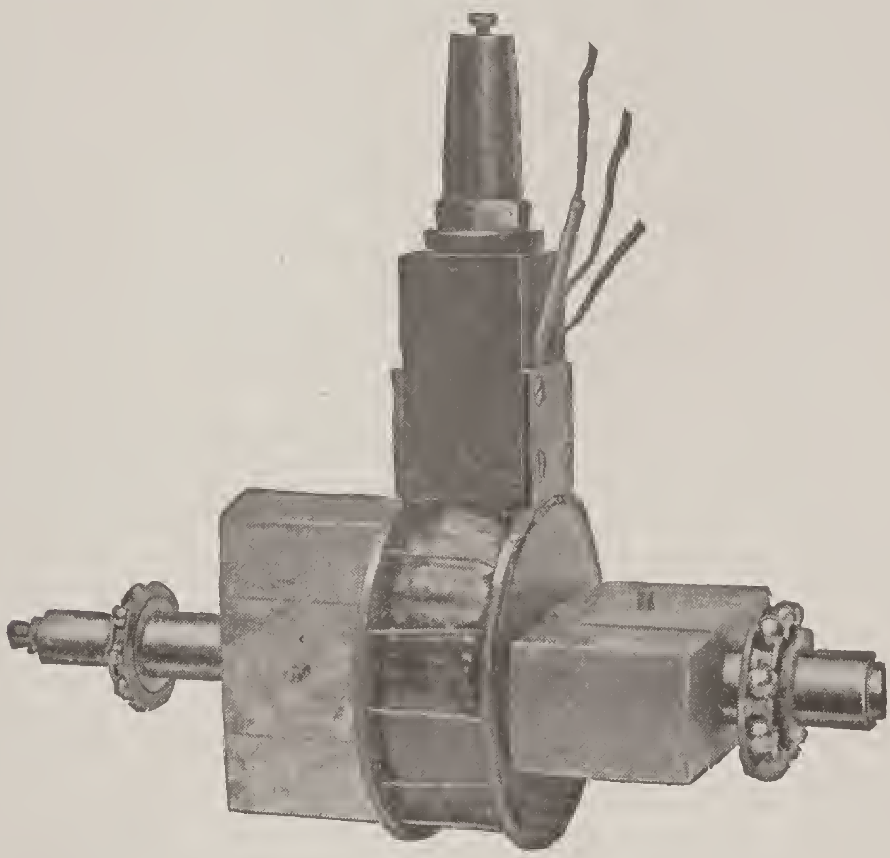


Fig. 67. Rotor and Winding of K-W Inductor Magneto
Courtesy of K. W. Ignition Company, Cleveland, Ohio

and, if the wires be connected to an outside resistance, a current will flow. This is the principle of the *inductor magneto* which is so termed because the current is induced in its winding instead of being directly generated in the latter.

Typical Construction Details and Current Production. The magnetic field is produced by permanent magnets in the same manner as on other types of magnetos and a mass of laminated soft iron is rotated between the pole pieces while the winding is stationary. The moving element is termed the rotor, and this part of the K-W high-tension magneto is shown in Fig. 67. The stationary

winding in the center is mounted on the shaft of the rotor and consists of a primary and secondary coil.

There is no mechanical or electrical connection between the windings and the rotor shaft, nor between the laminated blocks of the rotor and the windings. As shown in the illustration these are placed at right angles to one another and are riveted to the shaft. It will be evident that in the position shown in the illustration the right-hand member of the rotor will be bridging the pole pieces of

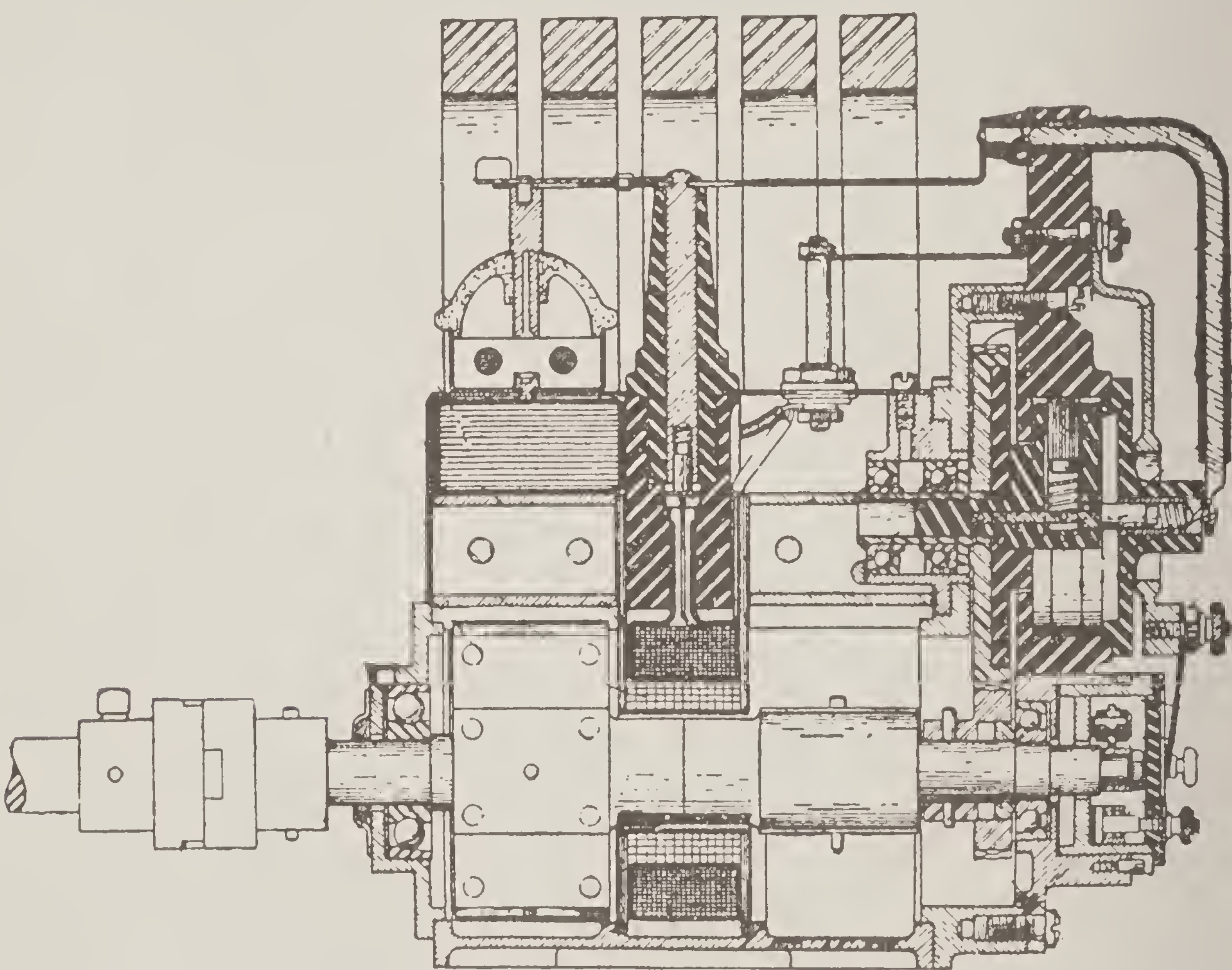


Fig. 68. Section through K-W Inductor Magneto
Courtesy of K. W. Ignition Company, Clevcland, Ohio

the magnetic field; by giving the shaft a quarter turn the two rotor members will have their ends facing opposite poles of the magnetic field, thus completing the magnetic circuit through the center of the windings. Consequently, a current wave will be produced each time the rotor revolves through a quarter-turn, or 90 degrees, so that this inductor magneto produces four impulses per revolution instead of two as in the ordinary type having a wound bipolar armature of H form. Apart from the method of producing the current, the remaining essentials of the magneto are the same,

except that no collector brush is necessary as is the case where the current is generated in a revolving winding on an armature.

The details of construction of the K-W high-tension magneto are shown in Fig. 68. While, from an external view of the rotor, it apparently consists of two independent parts, it will be seen in the section that it is practically one piece, the connecting part passing through the center of the winding so that the magnetic circuit is completed through the latter. The primary winding, consisting of four layers of comparatively coarse wire, will be noted close to the rotor; just outside of this is the secondary winding of many layers of fine wire and from the latter the connection is carried upward to a horizontal strip of copper termed a bus bar. At the right, this bar connects with the distributor for the high-tension current; at the left it connects with the safety gap, directly beneath which is the condenser.

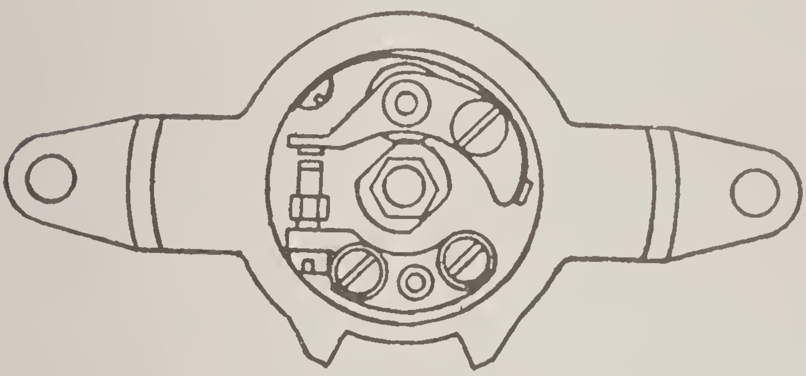


Fig. 69. K-W Interrupter

Timing. The magneto is timed by an interrupter operated by a cam on the rotor shaft in the usual manner; the details of this interrupter are shown in Fig. 69. As is the case with all ignition magnetos, these points remain closed, thus short-circuiting the primary winding, until the current reaches its maximum, and then are opened suddenly, thereby inducing a current in the secondary winding. The firing point of the magneto is just as the contact points begin to separate, as shown in Fig. 69, which is exaggerated to make this clear. At the same moment, the distributor arm is passing one of the segments connected to a spark plug, as shown in Fig. 70, the firing order of the motor in this case being 1, 2, 4, 3. While the magneto produces four waves per revolution, these are not necessarily all utilized; the cam (*c* in Fig. 70) opens the interrupter twice per revolution, giving two sparks for each turn of the crankshaft, as required by a four-cylinder four-cycle motor. In a four-cylinder two-cycle motor, a four-sided cam would be employed thus producing four sparks per revolution.

The letters on the illustration are: *A* contact breaker box; *c* cam;

P contact points of interrupter; *R* cam roller to lessen friction at that point; *B* distributor arm; *S* distributor segments; *RH* and *LH* referring to the direction of rotation, as either right hand—also termed "clockwise" or from left to right—and left hand, anti-clockwise.

Dixie Magneto. *Essential Elements; Circuits.* While based on the inductor principle, this differs from an inductor type of magneto in that the pole pieces themselves are revolved and they do not reverse their polarity as in the case of an inductor or an armature.

The rotating element of the Dixie is shown in Fig. 71; *B* is a brass block which prevents any magnetic flux flowing directly from

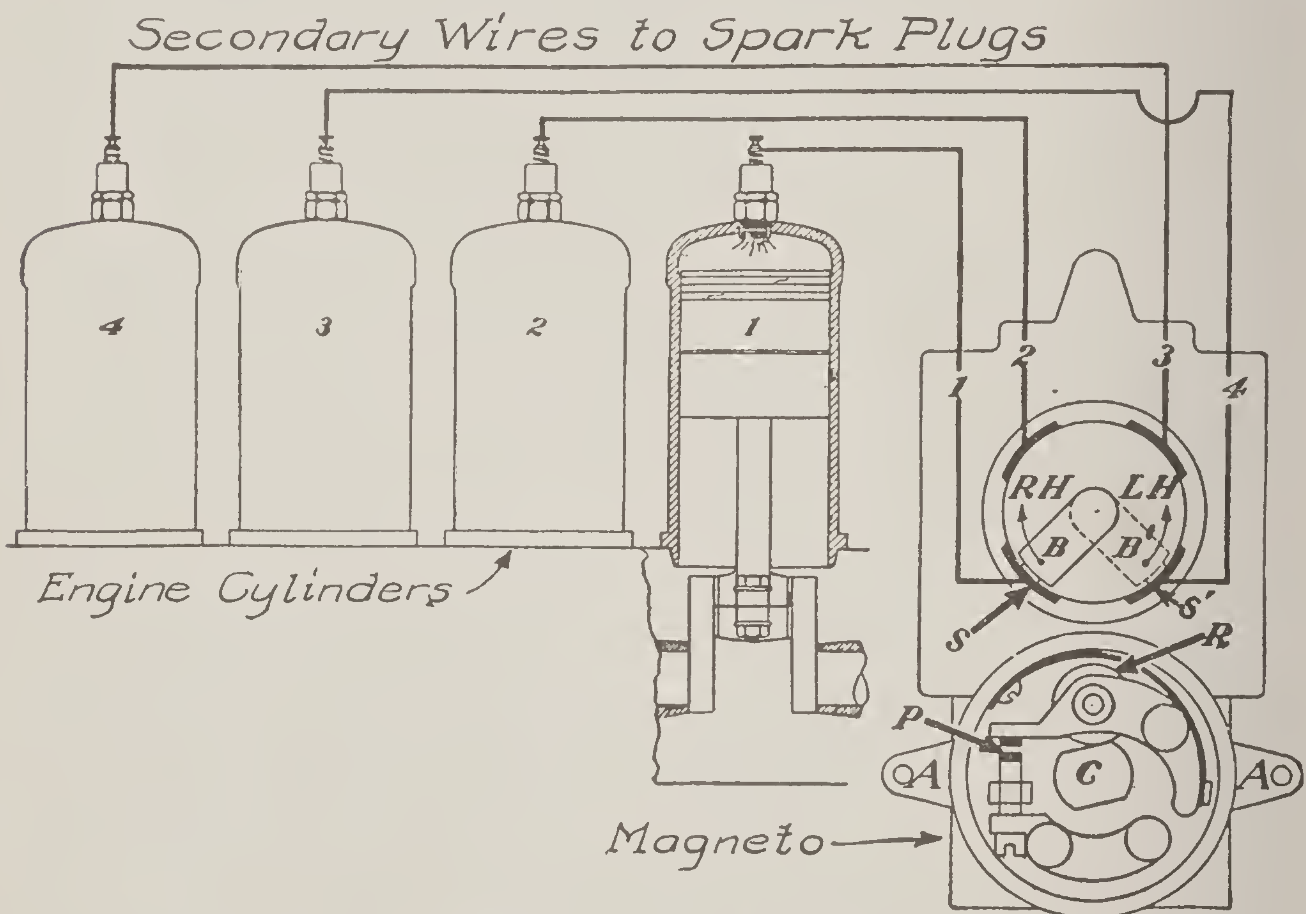


Fig. 70. Wiring Diagram for K-W Magneto Circuits

N to *S*, which are the rotating pole pieces. The coil with its primary and secondary windings is placed directly above this rotating element, in the hollow of the magnets, as shown in Fig. 72. At the right in the same figure is shown the relation between the rotor, the magnets, and the coil. It will be noted that the core of the coil *C* bridges the stationary pole pieces *F* and *G* and that the shaft of the rotor passes through the magnets in a plane at right angles to that of the usual magneto. The reversal of the magnetic flux, with varying positions of the rotor, is shown in the right-hand sketch of Fig. 72, and in Fig. 73.

The primary circuit of the Dixie is shown in Fig. 74; A being the core of the coil, P the primary winding, R the condenser, X and Y the points of the interrupter or contact breaker. The terminal D is a screw on the head of the coil, and the wire Z connects directly with the contact Y of the interrupter. Fig. 75 shows the details of this interrupter, the housing of which is attached to the mounting of the windings, while the details of the secondary circuit are shown in Fig. 76. C is the end of the high-tension, or secondary winding of

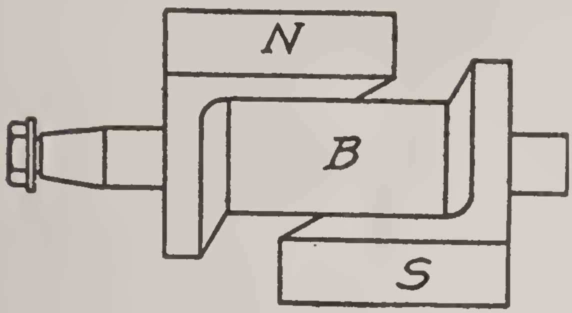


Fig. 71. Rotating Element of Dixie Magneto

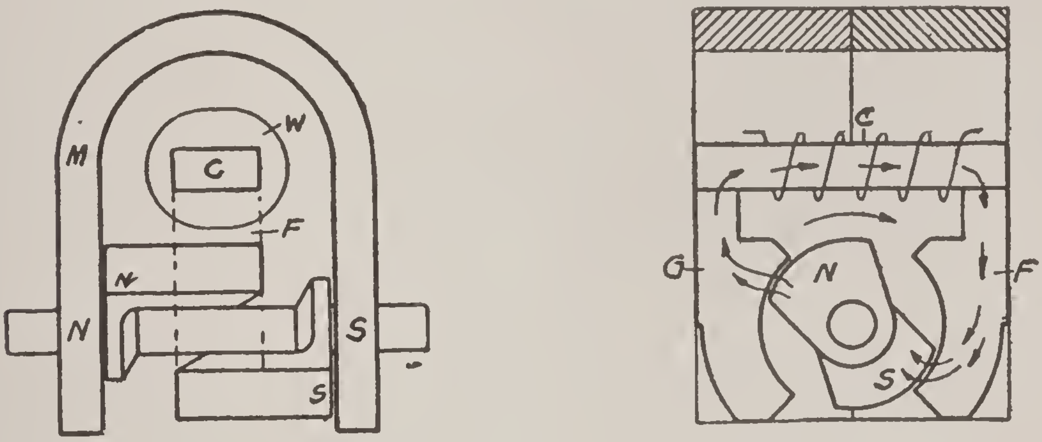


Fig. 72. Details of Dixie Magneto
Courtesy of Splitdorf Electrical Company, Newark, N. J.

the coil, which is connected to a metal plate D embedded in the hard-rubber end piece of the coil A. A small coil spring holds the

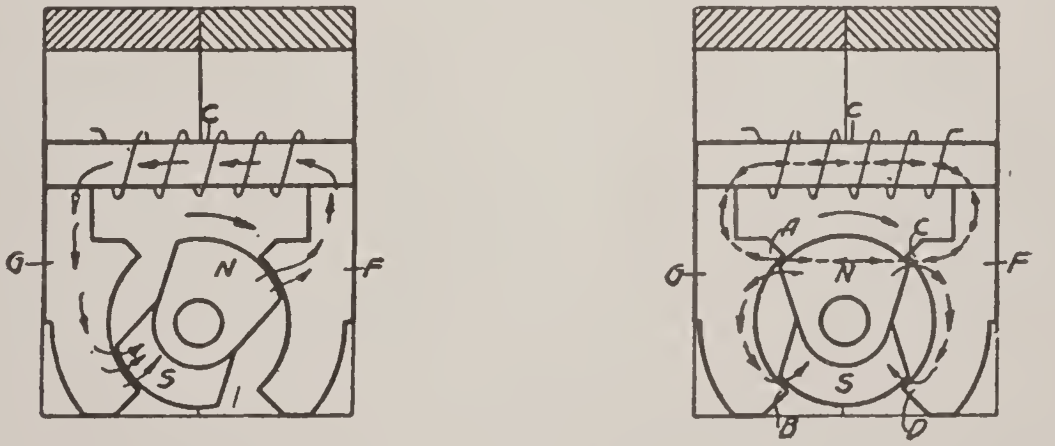


Fig. 73. Diagram Showing Reversal of Magnetic Flux in Dixie Magneto

connection F in contact with D and at its outer end F connects with J which is the distributor brush. The latter revolves, successively passing over the segments leading to the corresponding spark plugs.

But one of these segments is indicated by L, the dotted lines indicating the completion of the circuit through the ground connections.

Timing. As the contact-breaker box is attached to the mounting of the coil, the latter moves with it when the former is partly

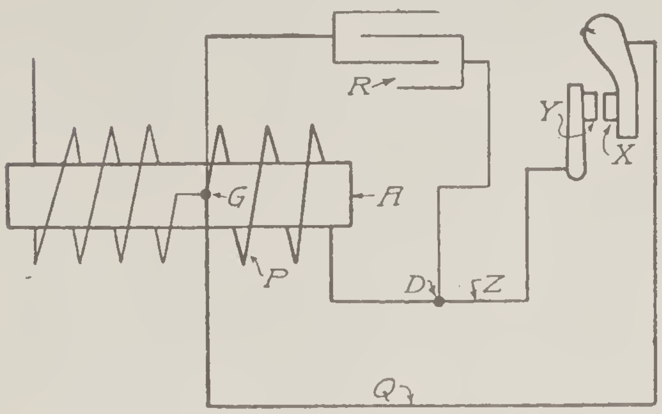


Fig. 74. Primary Circuit of Dixie Magneto

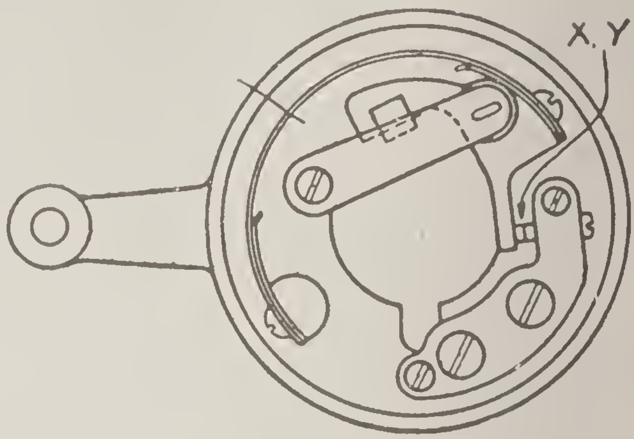


Fig. 75. Dixie Interrupter

rotated to advance or retard the occurrence of the spark in the cylinders, so that the opening of the contact points always takes place at the point of maximum current. This is shown diagrammatically in Fig. 77. As the contact points are opened by the revolution of the cam, it will be apparent that a movement of the mounting of these points with relation to the cam will alter the time at which they will operate. For example, assuming that the magneto is designed to run clockwise, moving the interrupter in the same direction as the rotation will cause the spark to occur later, as shown by the retarded position in the sketch. Moving the interrupter against the direction of rotation of the cam accordingly would cause the spark to occur earlier. The range of movement is approximately 15 degrees each side of the neutral point indicated by the horizontal position of the lever on the breaker box; the dotted lines show how the firing point may be advanced 15 degrees or retarded an equal amount. The lever in question is connected by means of linked rods to the spark lever on the steering wheel.

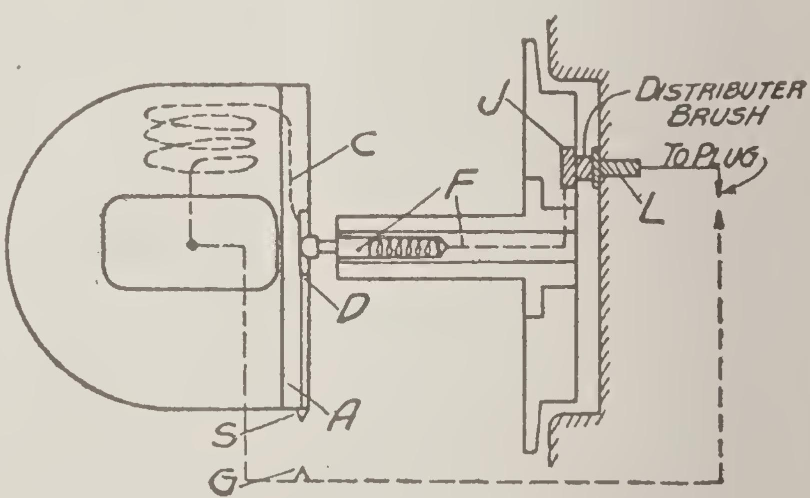


Fig. 76. Diagram of Secondary Circuit in Dixie Magneto

Magnetos for Eight-Cylinder and Twelve-Cylinder Motors. It will be evident that, regardless of the number of cylinders to be fired, the principles of current generation, transformation (to high tension), and distribution remain the same, so that a reference to

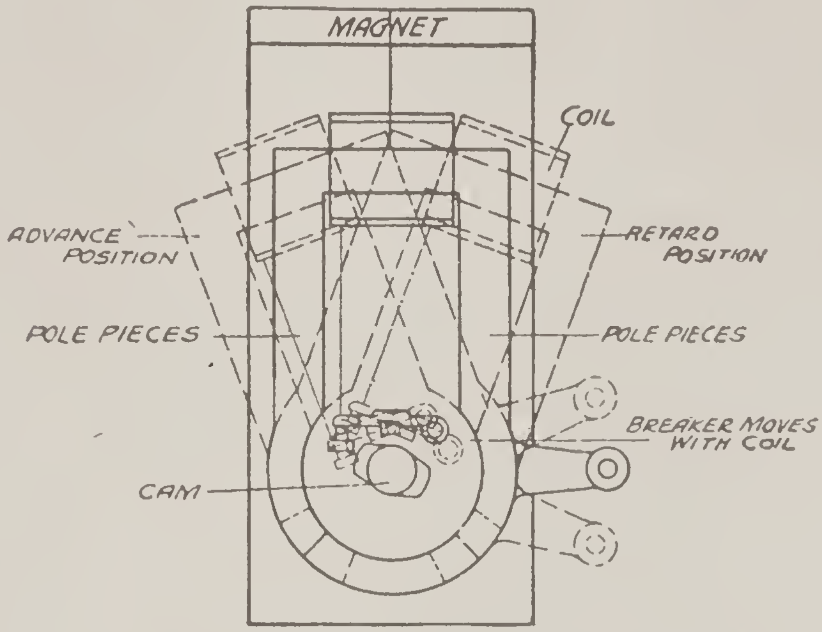


Fig. 77. Diagram Showing Method of Timing Dixie Magneto
Courtesy of Splitdorf Electrical Company, Newark, N. J.

the models of the Dixie for eight-cylinder and twelve-cylinder motors will suffice to cover the modifications required by the increased number of cylinders. To keep the speed of the magneto down, the rotor is provided with four poles instead of two, so that four impulses are generated in the windings per revolution. This permits of

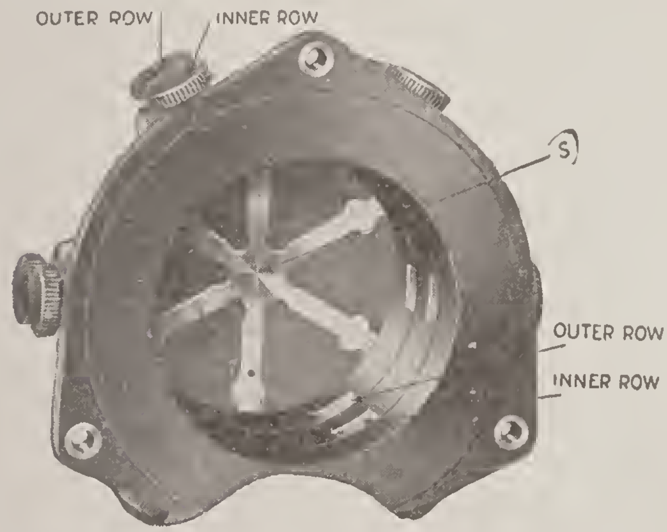


Fig. 78. Stationary Member of 12-Cylinder Splitdorf Distributor

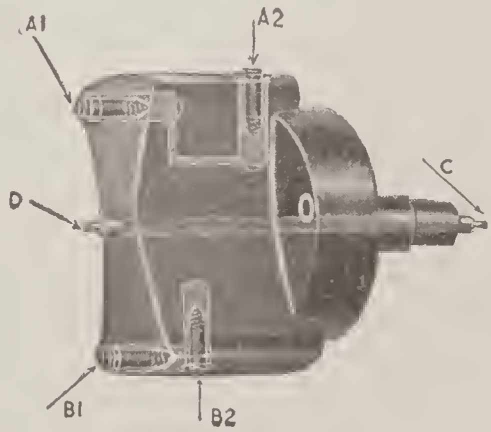


Fig. 79. Rotating Member of 12-Cylinder Distributor

running the magneto at crankshaft speed for an eight-cylinder motor and at $1\frac{1}{2}$ times crankshaft speed for a twelve-cylinder motor.

Compound Distributor. The contact breaker opens every quarter revolution instead of every half revolution—a cam with four

lifting faces being provided for this purpose—and the distributor is provided with twice as many segments and spark-plug leads as a magneto designed for four-cylinder or six-cylinder motors. But as the contact segments of the distributor must be sufficiently long to permit of the distributor brush being in contact with them, regardless of the point to which the ignition timing is advanced or retarded, it is impossible to place more than six contact segments in a circle without reducing the insulation between them to a point where there would be danger of the high-tension current jumping the gap and thus deranging the ignition. To avoid this a compound distributor is employed, i.e., two distributors are combined, but instead of being placed on a flat surface as in the magnetos for a smaller number of cylinders, the segments are spaced around the inner periphery of a hollow cylinder. Two radial contact brushes are carried by the revolving member of the distributor, each of which makes contact with one of the sets of segments. Fig. 78 illustrates the distributor itself, while Fig. 79 is the revolving member. The radial brushes *A*2 and *B*2 of Fig. 79 are electrically connected to contact brushes extending laterally (*A*1 and *B*1) from the revolving member. These brushes make contact alternately with the arms of a metal spider sunk flush in the end wall of the distributor, *S* in Fig. 78, with which the central pin of the distributor rotor *D*, Fig. 79, also connects. The high-tension current from the windings is fed to this distributor rotor through the spring brush contact *C*.

Path of Current. The path followed by the current is accordingly as follows: from the high-tension winding of the coil (not shown here) to the distributor rotor through the brush *C;* from brush *D* to the spider *S;* from *S* alternately through brushes *A*1 and *B*1 to the distributor segments representing the inner and outer row of spark-plug leads, through the brushes *A*2 and *B*2. Brushes *A*1 and *B*1 are so spaced that, when one is centrally in contact with an arm of the spider *S*, the other is midway between the second and third arms from the one with which contact is being made.

The relation of the various members of the Dixie magneto will be clear upon reference to the sectional view, Fig. 80, showing one of the four-cylinder models. The contact breaker or interrupter is at the left-hand end of the rotor shaft; just above the rotor itself is the coil, while to the left of this is the distributor.

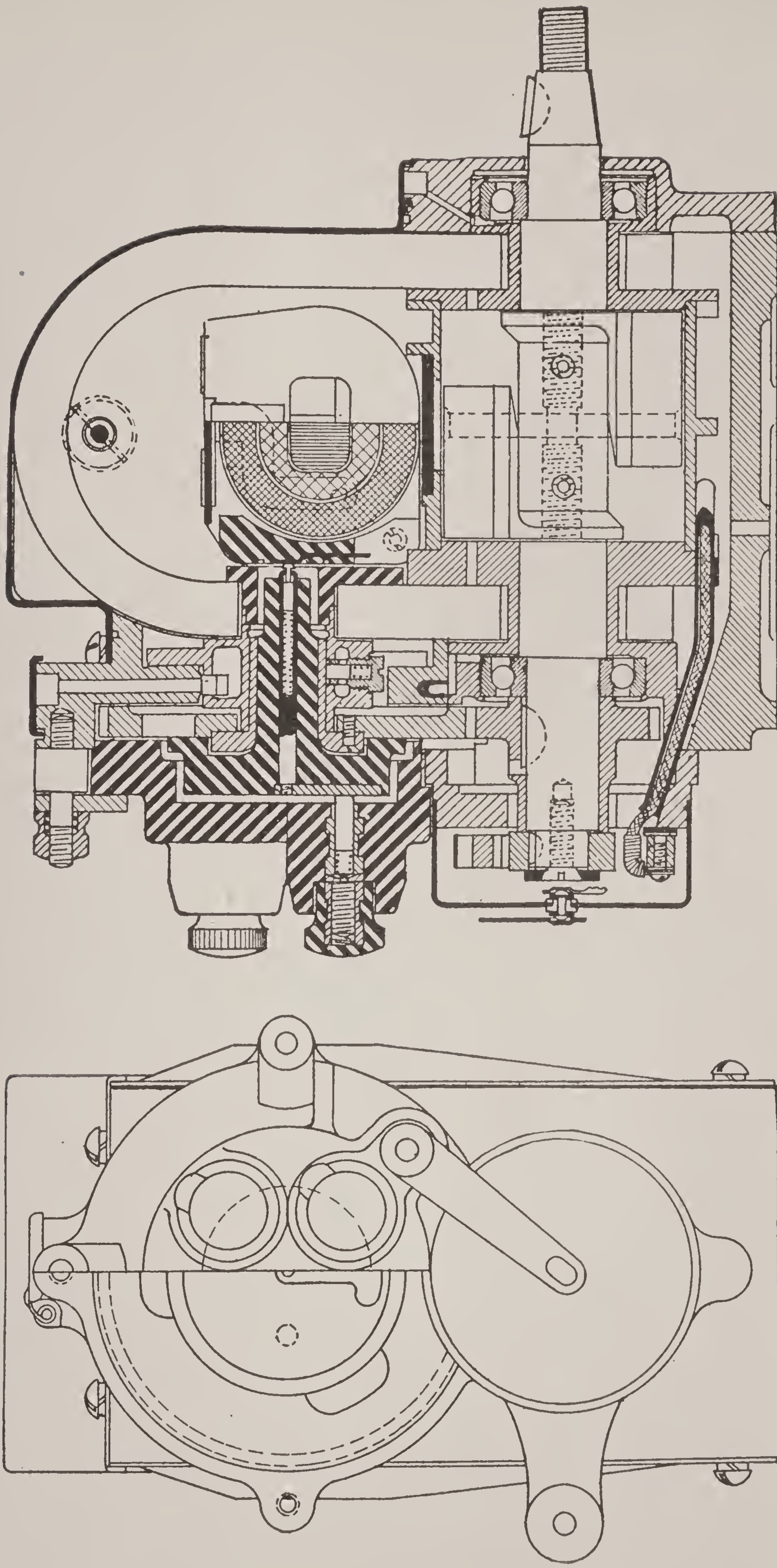


Fig. 80. End Elevation and Section of Dixie 4-Cylinder Magneto Showing Construction and Connections
Courtesy of "The Horseless Age"

IGNITION SYSTEMS

STANDARD TYPES

Dual Ignition System. *Bosch Type.* The dual type of ignition system uses one coil and one set of plugs with either the battery or the magneto as the source of current supply, the magneto contact breaker and distributor being common to both. Fig. 81 illustrates the connections of a dual system. Wire Number *1* is in the low-tension circuit and conducts the battery current from the primary winding of the coil to the contact breaker of the magneto. Low-tension wire Number *2* is the grounding wire by which the primary

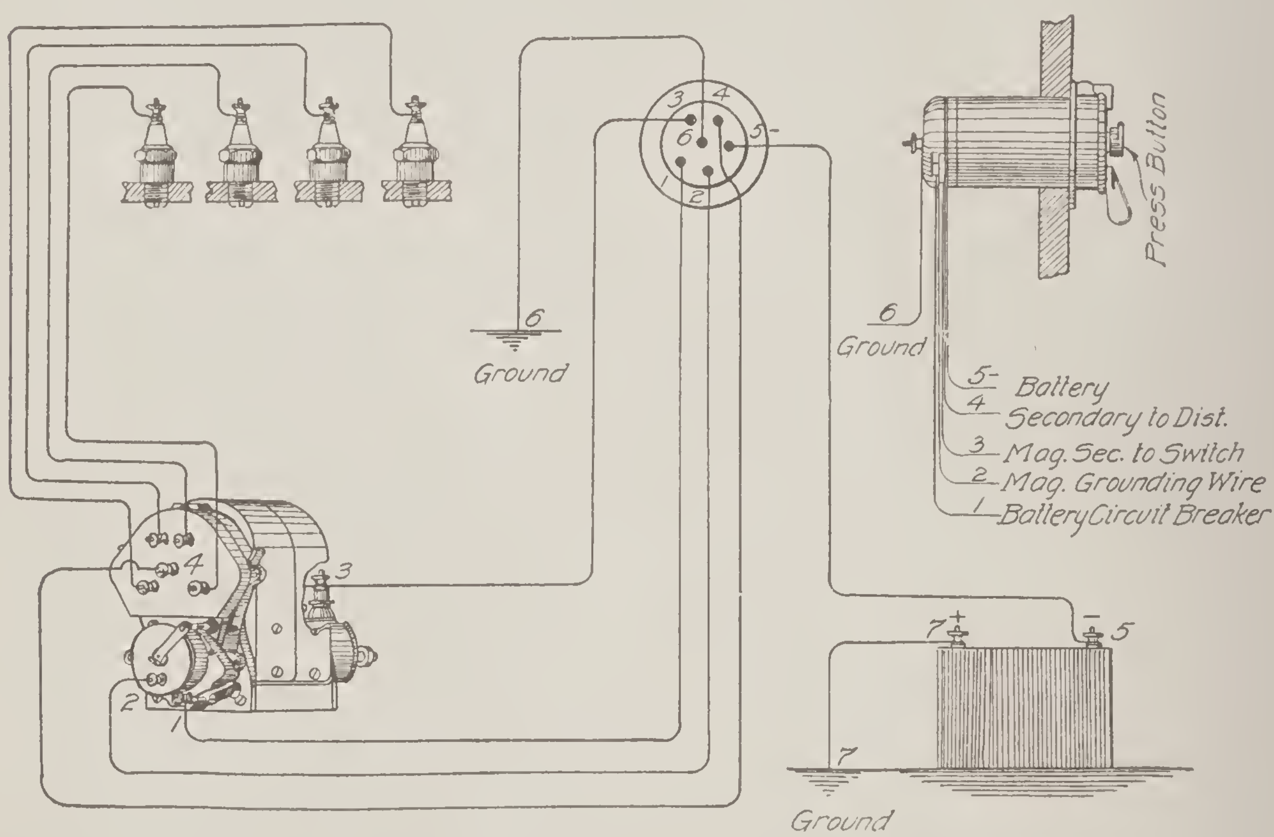


Fig. 81. Wiring Diagram Dual Ignition System

circuit of the magneto is grounded when the switch is thrown to the "off" or "battery" position. Wire Number *3* leads the high-tension current from the magneto to the switch contact, and wire Number *4* is the wire that carries the high-tension current from the coil to the distributor. Number *5* leads from the negative terminal of the battery to the coil, and the positive terminal of the battery is grounded by Number *7*; a second ground wire, Number *6*, is connected to the coil terminal. The press button on the switch cuts in the battery circuit which includes a special vibrator on the coil which is employed simply for "starting on the spark"; i.e., when a charge of gas is left in the cylinders and the crankshaft has stopped with

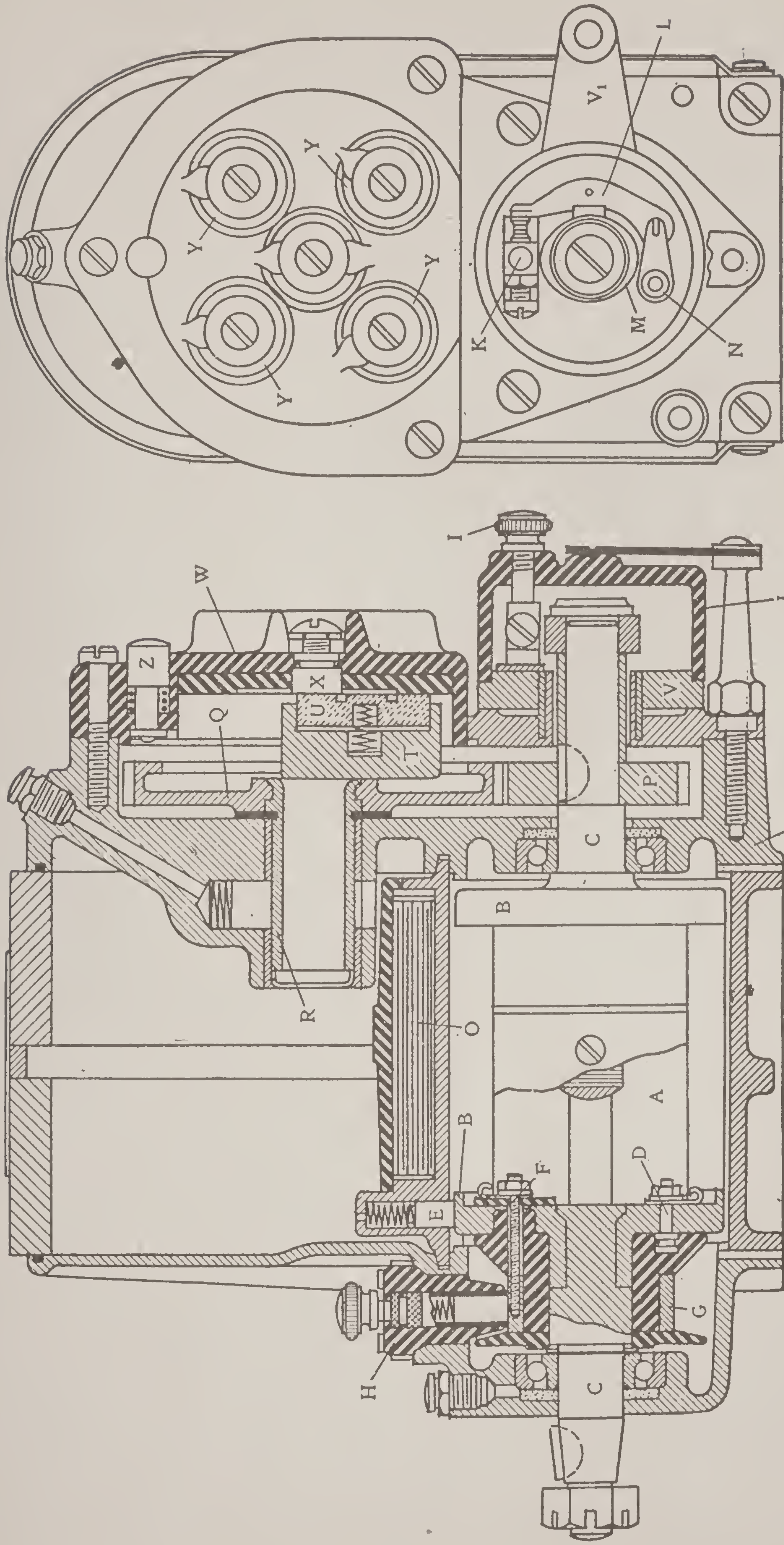


Fig. 82. Section and End Elevation of Remy Dual Type Magneto
Courtesy of "The Horseless Age"

the pistons in the proper position for firing the next one in order, a spark in that cylinder will frequently start the motor.

Remy Type. Prior to the general adoption of electric lighting and starting systems, the dual type of ignition system was almost universally employed on the lower and medium priced cars, many thousands of which are still in service. The Remy magneto, a section and end elevation of which are shown in Fig. 82, is typical of the class used for this service. The armature *A* is of the *H* or shuttle type, of laminated construction fitted with cast bronze heads *B*. It carries a single winding, one end of which is grounded by connecting it to the rear bronze head at *D*, the ground connection being further insured by the carbon brush *E*, pressed against the head by a spring. The other end of the armature winding is connected through an insulated stud *F* to the collector ring *G* from which the current is taken by a carbon brush in the holder *H*. From this brush a low-tension cable runs to the induction coil mounted on the dash.

The other primary terminal of the coil is connected to the terminal *I* on the breaker box at the right-hand end of the magneto. This terminal, which extends through the breaker-box cover *J* of insulating material, forms an integral part of the contact screw *K* which carries one of the contact points of the interrupter. The other contact point is mounted on the free end of the lever *L*, pivoted at its lower end and provided with a fiber contact block bearing against the cam *M* carried on the armature shaft. The contact screw *K*, interrupter lever *L*, and its stud *N* are all supported on the metal plate *V* forming the interrupter base. This plate is supported on a lateral projection from a disc secured to the forward end plate *S* of the magneto and is provided with the radial arm *V*, which is connected by jointed rods to the spark timing lever on the steering wheel. This permits of moving the breaker box through part of a revolution with relation to the cam on the armature shaft to advance or retard the time of ignition, as explained later under Spark Timing. The interrupter lever *L* is grounded to the frame of the magneto through the stud *N*. The condenser *O* is placed in the armature cover plate and has one terminal connected to the stationary contact screw *K* and the other terminal grounded, so that it is shunted or "bridged" directly across the interrupter and

serves to minimize the spark or arc caused by the opening of the contacts. The condenser is sometimes combined with the coil.

Details of Typical Distributor. Apart from slight variations in detail, the following description of the distributor is typical of all magneto distributors. At its right-hand end, the armature shaft, Fig. 81, carries the steel pinion *P*, which meshes with the bronze gear *Q* having twice the number of teeth. Rigidly mounted in the bronze distributor gear *Q* is a carbon brush *U* carried in the holder *T*. This brush is pressed by its spring against the inner surface of the insulating cover of the distributor *W*, in which are embedded a central contact block *X* and four or six (according to the number of cylinders) contact blocks *YY*, equally spaced about a circle. At their outer ends these contact blocks carry terminals for the attachment of the high-tension cables. As the distributor revolves it makes contact with the central block *X* and all of the blocks *YY* in succession.

Since the distributor gear *Q* has twice as many teeth as the armature pinion, it makes but one revolution for every two turns of the crankshaft (four-cylinder motor) and of the armature, the latter being driven at crankshaft speed. As the four-cylinder motor fires only twice per revolution, it is only necessary for the distributor to make one complete turn for every two revolutions of the crankshaft. The distributor is so geared to the armature shaft that it operates synchronously with the interrupter, i.e., whenever the contacts of the latter separate to open the magneto armature circuit and permit the current to flow through the primary of the coil, the brush *U* is on one of the contact blocks *Y*. The exact moment of opening is governed by the setting of the timing lever, but the distributor brush *U* is made of sufficient width to cover the contact block throughout the whole timing range. A feature of this model of the Remy magneto is the timing button *Z* fitted into the distributor cover, to facilitate the adjustment of the timing of the magneto to the motor. Most magnetos have to be disconnected from the driving shaft to accomplish this. This button is normally held out by its coil spring. If the button is pressed in and the armature shaft is then turned, the plunger of the button will drop into a recess in the distributor gear. Then the engine must be turned over by hand until the piston of cylinder No. 1 is exactly

at the upper dead-center position at the beginning of the power stroke, and while the crankshaft of the engine and the armature shaft of the magneto are in these relative positions, the magneto driving gears must be meshed and the magneto gear secured on the tapered end of the armature shaft by means of a Woodruff key which is held in place by a bushing and nut, as shown in the sectional view, Fig. 82.

Typical Wiring Diagram. Fig. 83 is a wiring diagram of a typical dual-ignition system that illustrates the connections in greater detail than in the case of the Bosch system. The switch

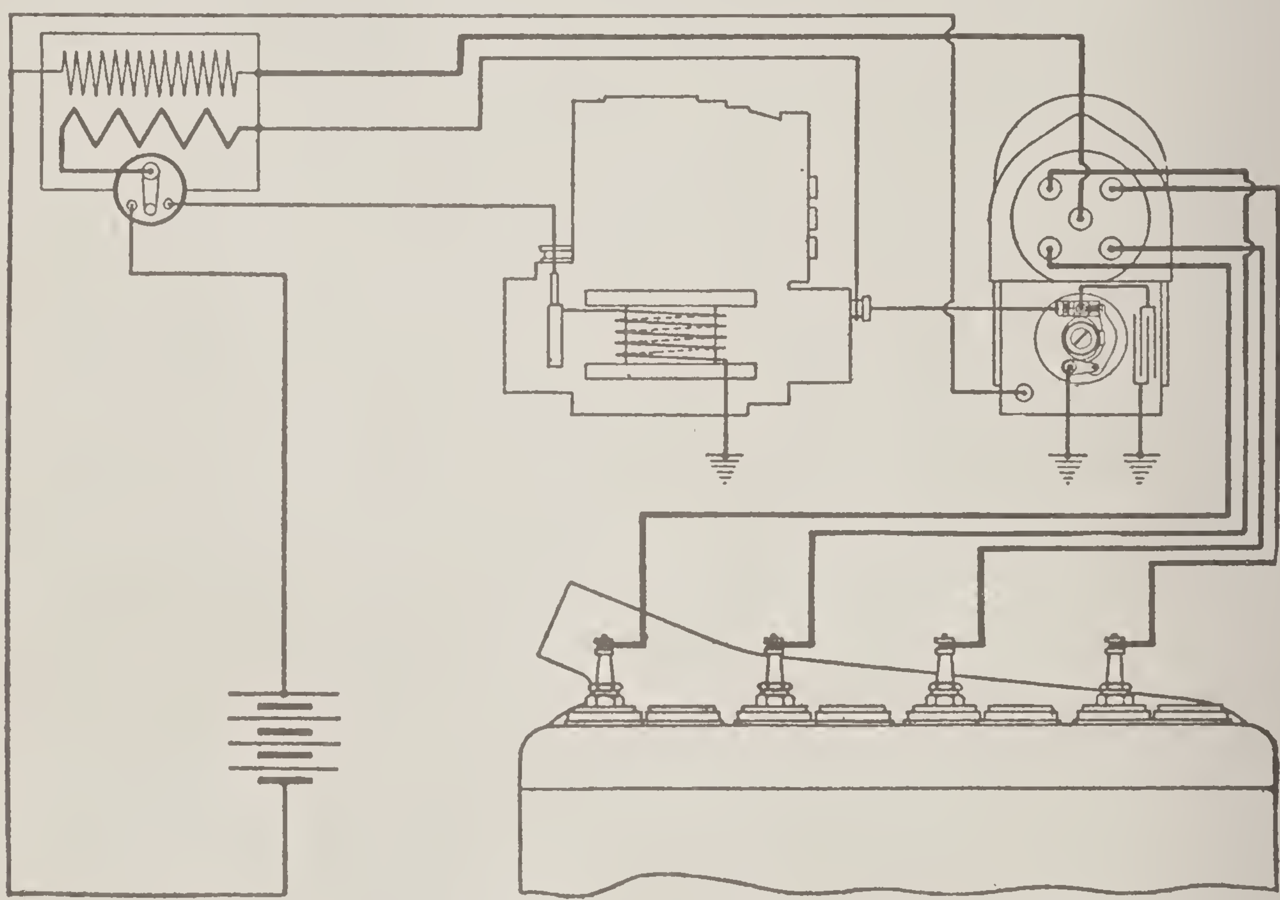


Fig. 83. Wiring Diagram of Magneto and Coil in the Remy Dual System
Courtesy of "The Horseless Age"

shown just below the induction coil has three positions: "OFF" (central); "BATTERY" (left); and "MAGNETO" (right). When the switch is on the BATTERY contact, the current flows from the battery through the switch and the primary winding of the coil to the interrupter, and completes the circuit by means of the ground connection of the latter and the coil. The secondary current is distributed in exactly the same manner as when the armature of the magneto is supplying the low-tension current. As the interrupter has its contacts closed, except for the momentary break when the spark occurs, its demand upon the battery is large, so that the

switch should immediately be shifted to MAGNETO as soon as the engine starts. Otherwise a dry-cell battery will be exhausted in a comparatively short time, or an unnecessary drain will be made from the storage battery where the latter is employed for starting.

Duplex Ignition System. This is designed to facilitate the starting of the motor by utilizing the current from a battery as well as that from the magneto when cranking to start. To throw the battery current in phase with that of the magneto, it having previously been stepped up to high tension through a coil on the dash, a commutator is fitted to the magneto shaft. The magneto is of the

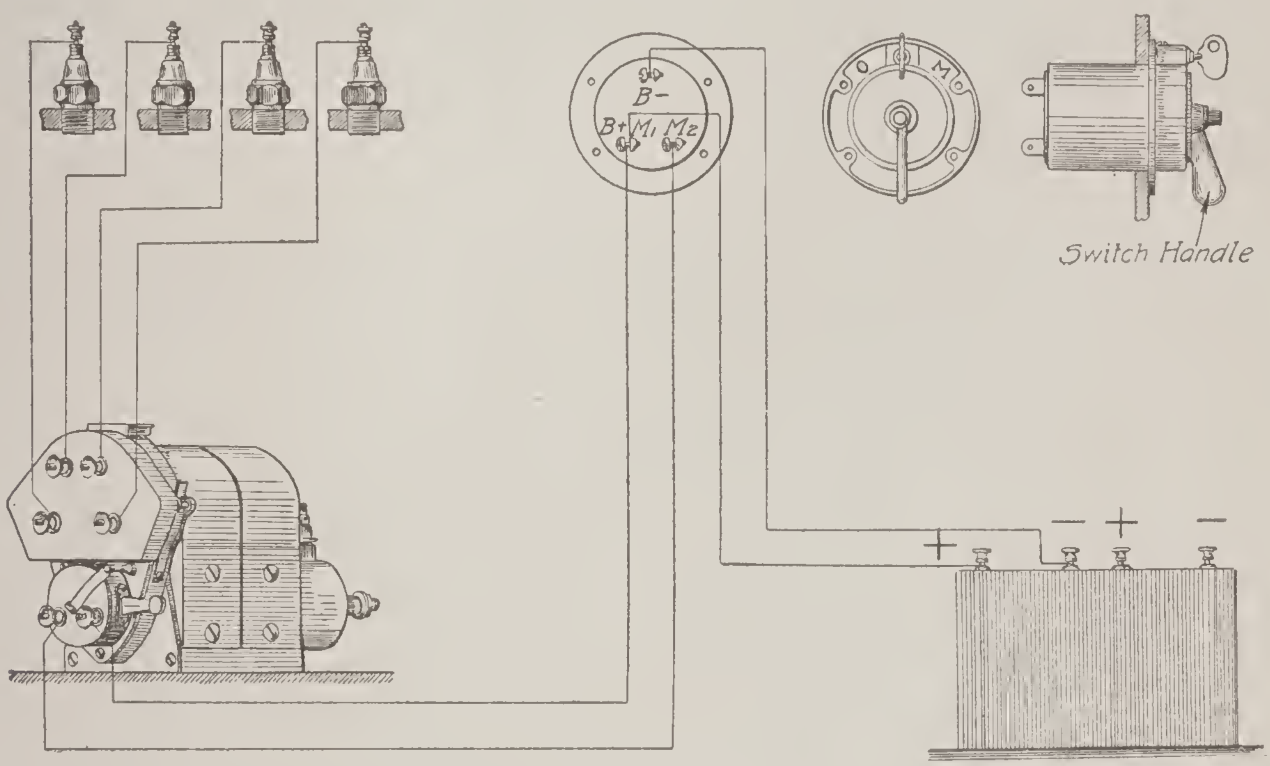


Fig. 84. Wiring Diagram of Bosch Duplex Ignition System

true high-tension or independent type, and by means of this commutator the flow of battery current is in the same direction as the flow of magneto current, a change in the direction of one (alternating current as generated by the magneto) is accompanied by a change in the direction of the other, and they are said to be "in phase," i.e., the cycles of alternation correspond in both. To accomplish this the battery current's polarity must be the same as that of the magneto and the battery must not be grounded, as shown by the wiring diagram, Fig. 84. The necessity for using the battery current to supplement that of the magneto exists only at very low cranking speeds, and the assistance of the battery is no longer needed once the engine starts. This type is not in general use.

Double-Spark Ignition. Mention has already been made of the employment of two sparks occurring simultaneously in the cylinders under the head of "Series Plugs". It will be evident that simply by adding another distributor to a magneto and taking leads from it to a second set of plugs placed at another point in the cylinders, preferably as far away from the first as possible, the same result is accomplished. Fig. 85 shows a Remy two-spark magneto, the distributors being mounted at opposite ends of the field.

Fig. 85. Remy Two-Spark Magneto

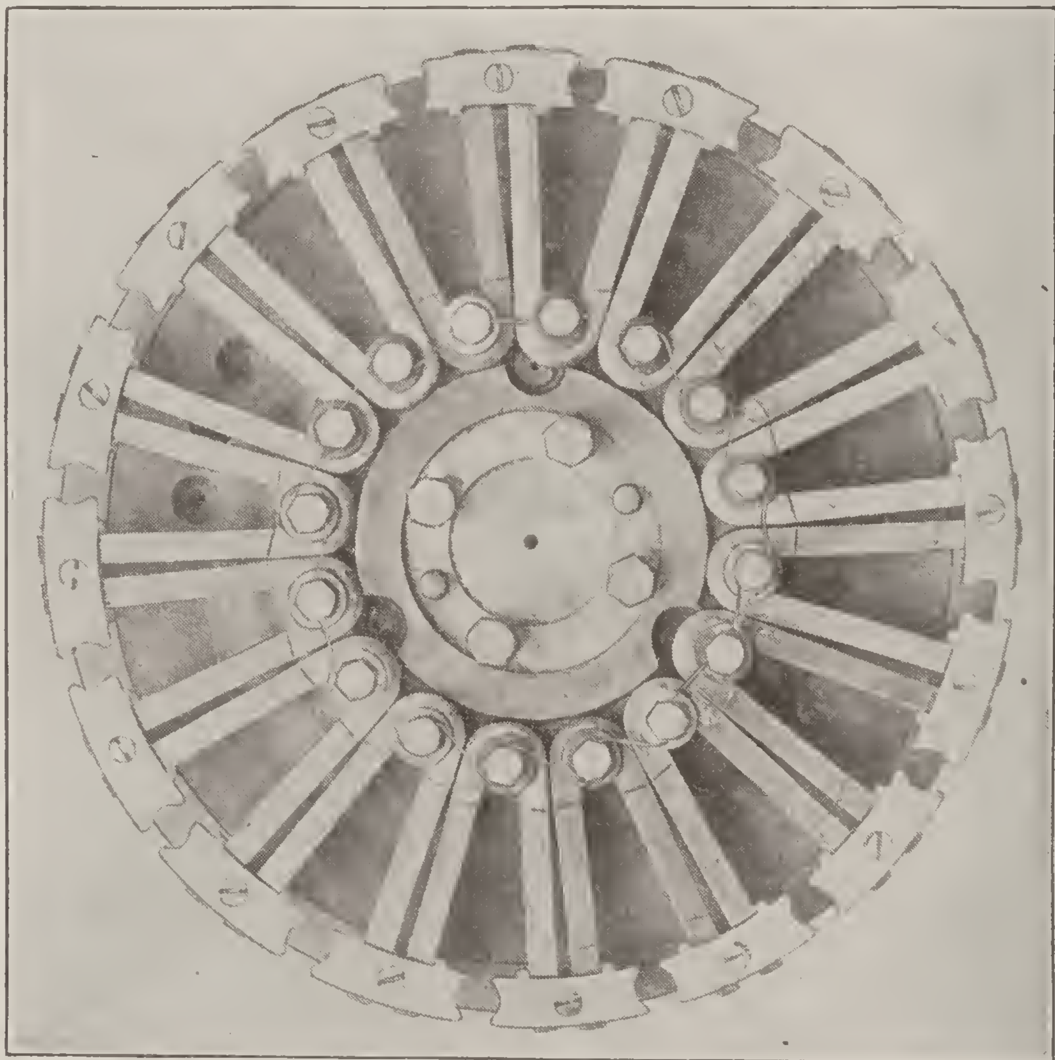


Fig. 86. Magnets of Ford Magneto

Ford Magneto. The Ford magneto is *sui generis*. What the patent lawyers term the "prior art" shows nothing even vaguely resembling it and no ignition current generator used on either

American or foreign cars, past or present, can lay claim to any family ties. Not that its principles differ in any way, but their application is very unusual, and as this magneto is now employed on more

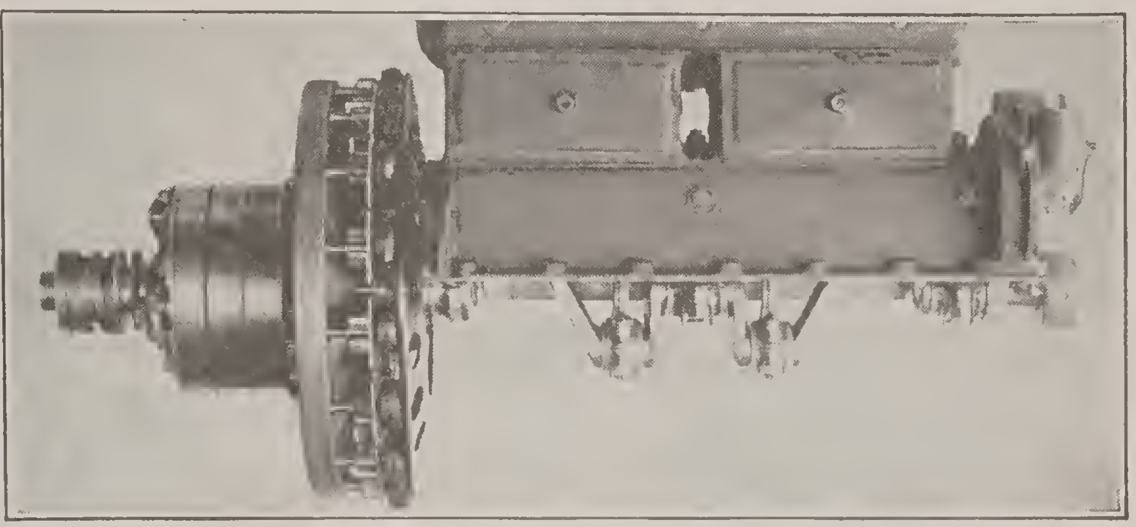


Fig. 87. Ford Magneto as Installed

than a million cars, it is of particular interest. Instead of the two or three horseshoe permanent magnets employed on the ordinary magneto, the Ford has sixteen magnets arranged radially with their poles outward, and all are bolted directly to the flywheel, as shown in Fig. 86. Directly in front of them and separated by a very small

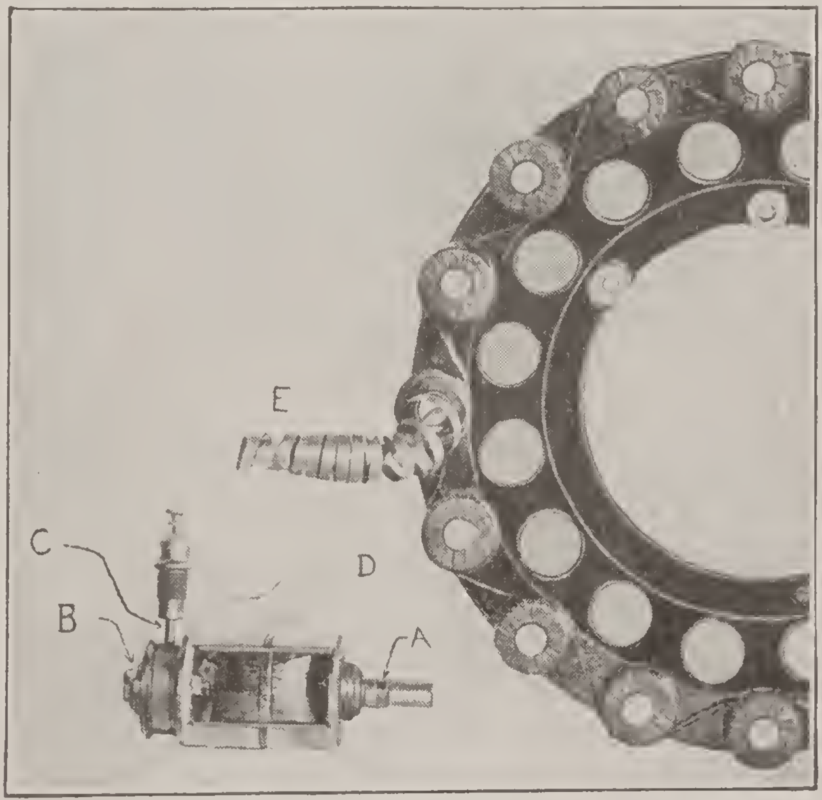


Fig. 88. Copper Ribbon Coils of Ford Magneto

clearance are sixteen coils, wound of copper strip or ribbon and attached to a spider which is bolted to the crankcase of the motor just forward of the flywheel, as shown by Fig. 87. The spider itself

and the coils are illustrated by Fig. 88, which shows one of the coils partly unwound at *E*. The spider and its coils remain stationary while the magnets are rotated in close proximity to them at high speed by the flywheel, thus inducing a current in the coil windings. The current is taken from the collector ring *B*, through the single brush *C*, the other side of the magneto circuit being grounded. Fig. 89 shows the complete ignition system as installed on the motor. The magneto is shown with part of its housing removed; at its upper center is the collecting brush mentioned, connected to the four-unit

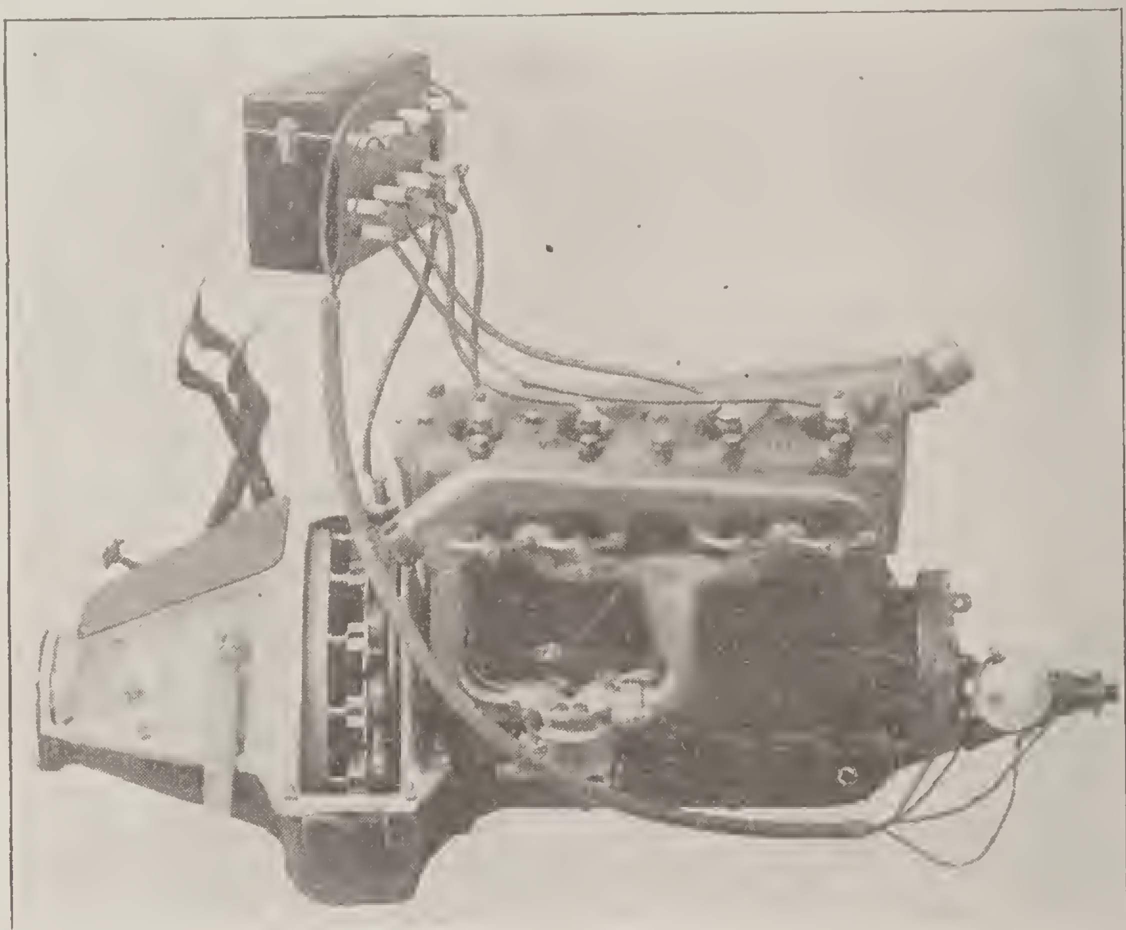


Fig. 89. Complete Ford Ignition System

coil, which in practice is mounted on the dash. From the coil, four primary connections are made to the low-tension timer mounted at the forward end of the motor and driven from the camshaft, and the four high-tension cables for the spark plugs will be noted just below the primary connections. The other two binding posts on the back of the coil are for the current from the magneto and the ground connection. While a battery is ordinarily fitted in addition to facilitate starting, this can be accomplished on the magneto alone, as the latter is very powerful. Replacements are sold at such low prices that when the magnets have lost their strength, new ones often are inserted instead of remagnetizing the old.

Current Supply and Distribution. Except for the use of a magneto to supply the current, the system will be recognized as the ordinary coil-and-battery type now long obsolete (1909 and earlier models). Instead of the direct current provided by a battery, however, the Ford magneto supplies an alternating current which alternates sixteen times per revolution. Between each alternation, there is, of course, a momentary drop to zero so that, at the positions of the crankshaft and field magnets corresponding to this drop, there is no current in the armature, or so little that it is impossible to produce a spark. Assuming that, when the timer completes the primary

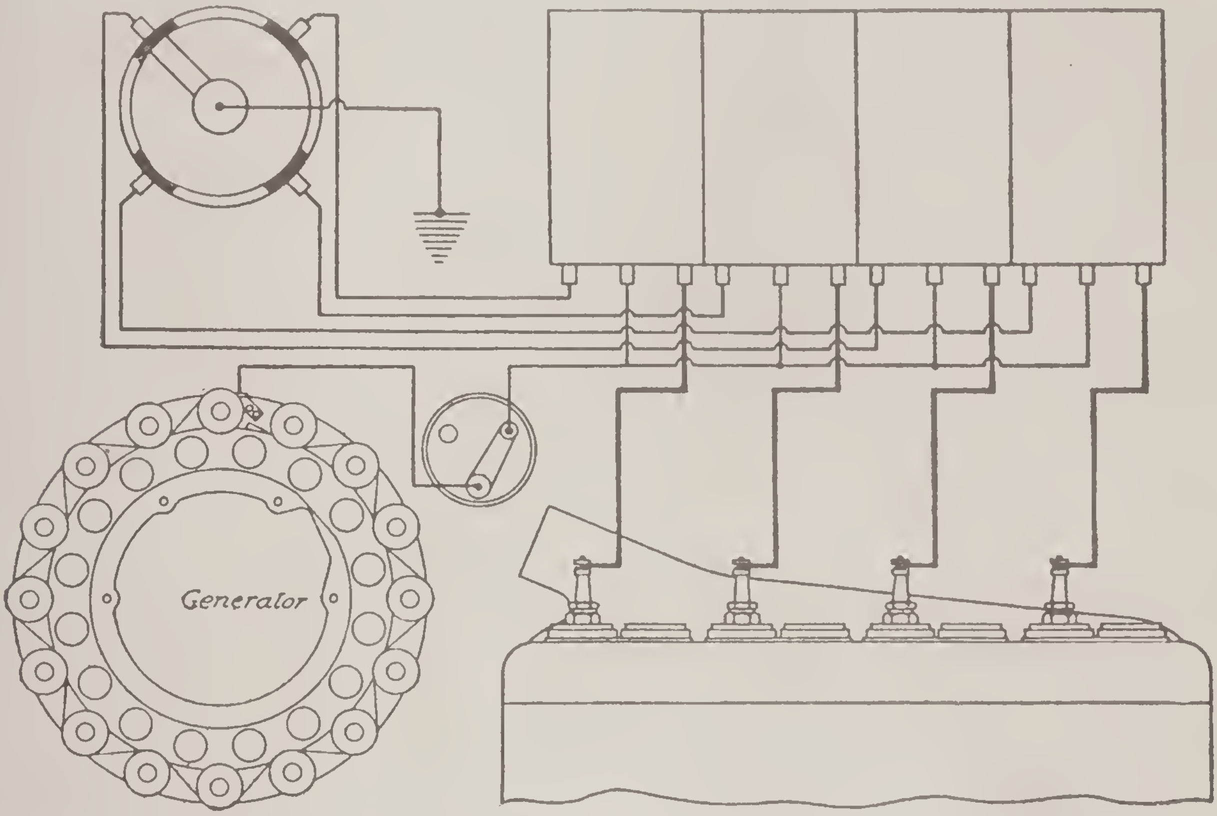


Fig. 90. Wiring Diagram for Ford Ignition System
Courtesy of "The Horseless Age"

circuit, the magneto is at or very near the position of zero e.m.f., the coil vibrator will not respond as the current sent through the coil by this very weak e.m.f. is not sufficient to operate it. As soon, however, as the current attains the minimum value necessary to attract the vibrator, a spark is produced. The result of this is that, as the spark timing lever is moved over its quadrant, the spark is not advanced uniformly with the lever motion. It doubtless also accounts for the fact that the motor will often be found to run much better with the lever advanced but a short part of its travel, instead of at the point of maximum advance as is the case with the ordinary magneto or with the modern battery system.

Fig. 90 shows the wiring diagram of the Ford ignition system, the primary timer being indicated just above the magneto or generator. To operate efficiently, this timer needs oiling daily when the car is in constant service, and in cold weather about 25 per cent of kerosene should be added to the oil used for this purpose, as the low temperature causes the latter to thicken. To the right of the generator are shown the switch, the four vibrator coils, and the spark plugs with their leads. As the magneto has but one collector brush, it is subject to few troubles. The collector brush may loosen up through vibration and may not make proper contact, or dirt and oil may collect on the ring against which it bears, with the same result. Apart from this, the chief trouble will be caused by weakening of the magnets. A current sent through the armature coils from an outside source will tend either to strengthen or to weaken their magnetism, depending upon the direction of the current itself and the relative position of the armature with regard to the magnets. As the armature is always likely to stop in such a position that a current sent through it from an outside source will weaken the magnets, a battery should never be connected to the armature.

Misfiring. Irregular firing can be traced most frequently to the timer and will be caused either by a lack of oil or an accumulation of dirt; with the timer in good condition, misfiring will most often be due to a lack of uniformity in the adjustment of the vibrators, or to worn and pitted vibrator contacts. With the motor running, the vibrator adjustment screws should be turned up or down very slowly until all four cylinders fire uniformly. Instructions for taking care of the vibrator points are given in detail in connection with the description of battery cut-outs and circuit breakers in Part III, Starting and Lighting Systems. Failure to fire is usually due to lack of contact at the collector brush on the magneto. The timer is so located that the primary cables get the full benefit of all oil and dirt, while its movement to advance or retard the ignition is also apt to abrade the insulation from these wires close to the timer, so that irregular firing may also be due to this cause. Complete wiring replacements may be had at such low cost that when the cables become oil soaked and their insulation worn, the easiest way to correct troubles from this source is to install a new set of connections.

SPARK TIMING

Effect of Irregular Sparking. Like a steam engine, an internal combustion motor depends for its power output on the mean effective pressure developed in the cylinder, usually referred to as its m.e.p. This is affected directly by three factors: *first,* the initial compression of the charge, that is, the pressure to which the piston compresses the gaseous mixture on its upward or compression stroke just before firing; *second,* the time at which the charge is ignited; and *third,* the length of the stroke. It is with the second factor alone that this phase of the ignition problem is concerned. In contrast with the steam engine in which the steam as admitted is at a comparatively low pressure and expands gradually throughout the stroke, the pressure developed in the internal combustion motor at the moment of ignition is tremendous, but it falls off very rapidly. The impulse given the piston is more in the form of a sharp blow than a steady push, as with steam. The mean effective pressure developed depends very largely upon the pressure reached at the moment of explosion and this in turn depends upon the time ignition occurs with relation to the stroke. As the speed of an automobile motor varies over a wide range, it will be apparent that means must be employed for varying the time of explosion. To be most efficient it must occur at the point of maximum compression, i.e., when the piston is exactly at the upper dead center on the compression stroke. As both a mechanical and an electrical lag, or delay, must be compensated for, the setting which will give maximum efficiency at 500 r.p.m. will be much too slow at 1500 r.p.m. and the spark would then not take place until after the piston had started down again and the pressure had dropped considerably, causing a great loss in power. On the other hand, an attempt to run the motor slowly with a spark timing that would give the best results at high speed would often result in causing the explosion to take place against the rising piston. This is evidenced by a hammering sound and a great falling off in the power.

Advance and Retard. Means are accordingly provided in the majority of ignition systems for causing the spark to occur earlier or later in the cylinders. This is termed advancing and retarding the spark, the nomenclature being taken from the French, with whom it originated. The explanation given in the preceding paragraph

for the necessity of this will make plain the car maker's often repeated injunction to the novice—never to drive *with the spark retarded.* Another and equally important reason is that when operated this way, the combustion is incomplete, the gas continues to burn throughout the stroke, and a greatly increased percentage of its heat has to be absorbed by the water jackets, causing the motor to overheat badly.

Adjusting for Time Factor of Coil. Every induction coil has a certain time constant, which represents the period necessary to completely charge the coil, that is, the time required for the current in the primary winding to attain its maximum value. This time constant depends very largely upon the amount of magnetic energy which can be stored up in the coil. There must be added to this the time required to overcome the inertia of moving parts, such as the timer and the vibrators of a high-tension battery system, or the contact breaker and the distributor in a magneto high-tension system. As these parts are very small and light this would be practically negligible for any other purpose, but when figuring in hundredths of a second, as in the case of the ignition timing of high-speed multi-cylinder motors, it becomes of importance. The object sought, as already mentioned, is to have the spark always occur at the point of maximum compression. To accomplish this with the motor running at high speed, the ignition devices must act while the piston is still an appreciable distance below upper dead center. The timer in the case of a battery system, or the contact breaker of a magneto, is accordingly mounted so that it can be turned through part of a revolution with relation to its driving shaft, or more particularly the cam carried by the latter. For starting the motor by hand, the spark must occur either at or after upper dead center is reached, never before. In the latter case, the piston would be driven backward and the familiar "back kick" result. Hence the manufacturer's admonition—always retard the spark fully before attempting to crank the motor.

Calculation of Small Time Allowance. The relation of spark advance in degrees to piston travel in inches with motors having strokes running from 3 to 8 inches is shown by the accompanying chart, Fig. 91. In this the ratio between the crank and the connecting rod length is 1 to 4.5. The lettering shown indicates the method

of using the chart, the problem being to find the piston travel for an advance of 30 degrees in a motor of 6-inch stroke. The vertical line *a*, corresponding to this stroke, is traced upward until it intersects the 30-degree line at *c*; following the latter to the left brings it out at a

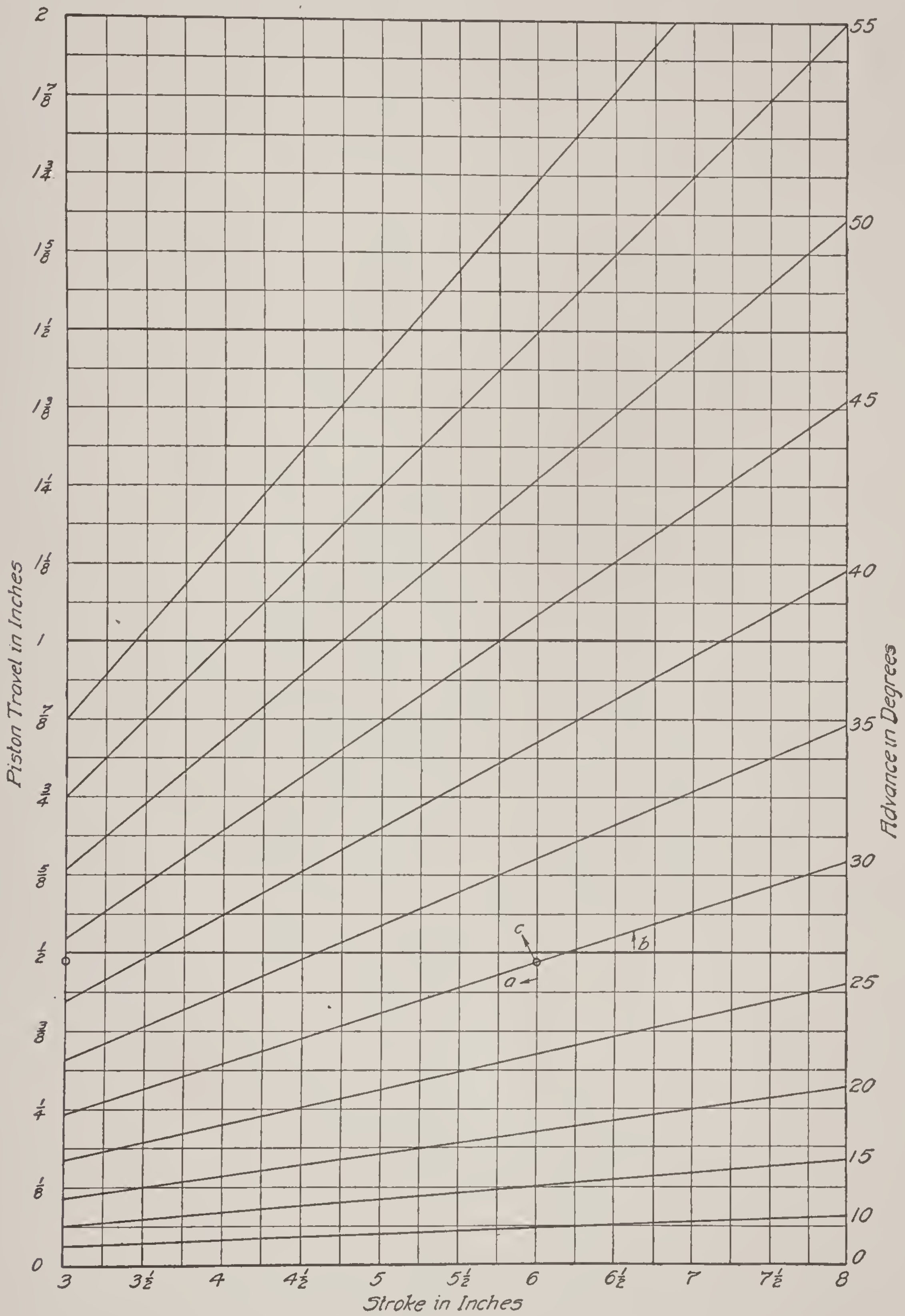


Fig. 91. Relation of Spark Advance to Piston Travel (Bosch)

point just below the ½-inch division, or approximately .46 inch. Assuming that the 6-inch stroke motor were running at 1800 r.p.m., its pistons would be traveling 1800 feet per minute (i.e., stroke doubled or 1 foot per revolution), 30 feet, or 360 inches per second,

so that each inch of the stroke would be covered at an average speed of 1 inch in $\frac{1}{360}$ of a second, and the $\frac{1}{2}$ inch in $\frac{1}{720}$ of a second, from which the necessity for a timing allowance will be apparent.

Magneto Timing. Timing is usually 30 to 40 degrees, which means that the spark occurrence can be advanced or retarded half that distance from a neutral line representing the upper dead center position of the piston. As shown by Fig. 92, the allowance is 34 degrees in the Splitdorf magneto, "left" and "right" in this connection having

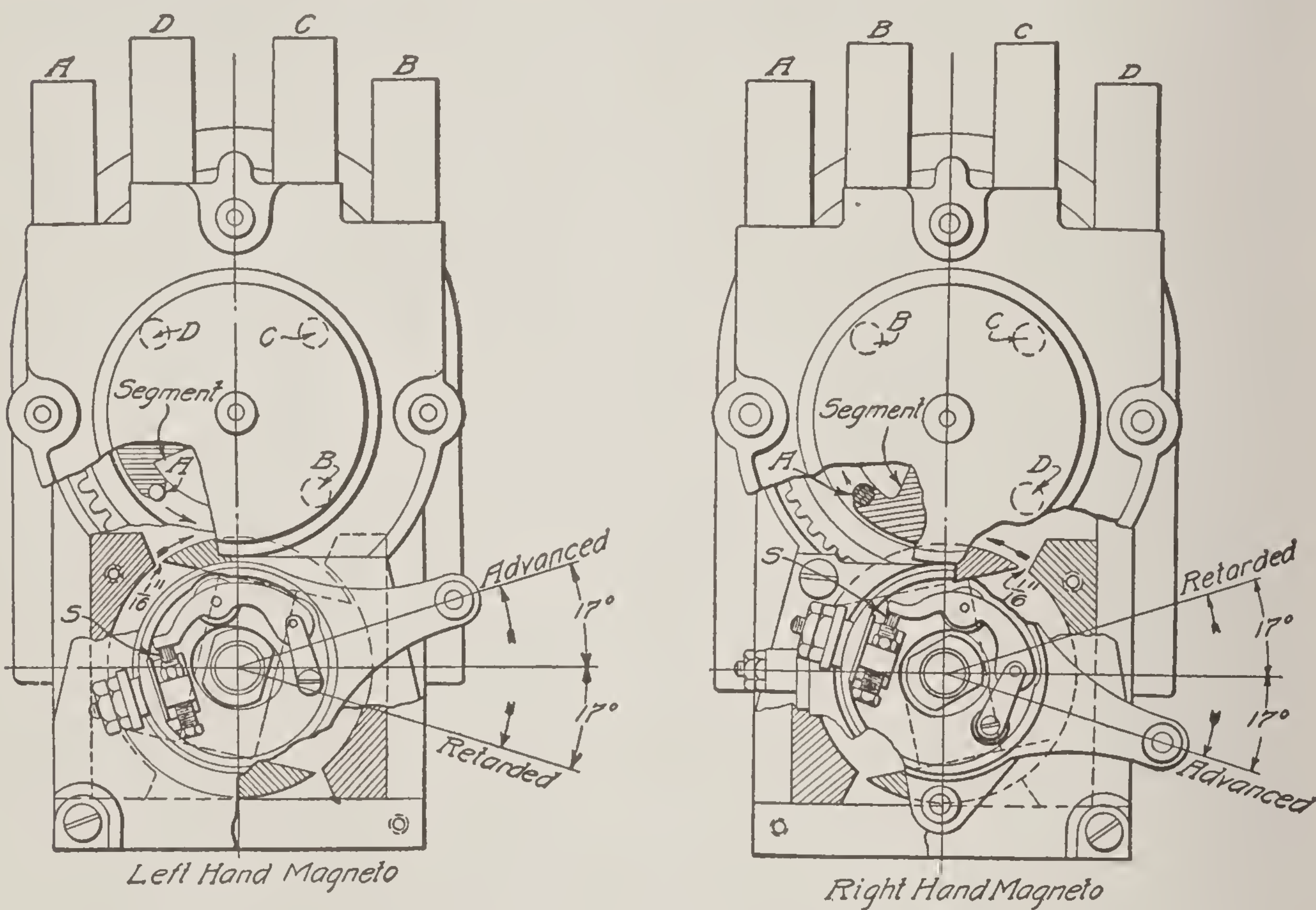


Fig. 92. Method of Advancing and Retarding Spark, Splitdorf Magneto

reference to the direction in which the magneto armature is driven. The necessity of providing this allowance, however, introduces a complicating factor in magneto design.

As the timing of the spark is accomplished by opening the contact points of the interrupter earlier or later, it will be apparent that as the magnetic field remains stationary in the ordinary magneto, the relative positions of the armature and field vary. This is illustrated by the sketch, Fig. 93, the left-hand member of which shows the position of the armature with *advanced spark.* This is the point at which the current and voltage are at their maximum, so that the most efficient spark is produced at the plugs. With the spark retarded, the armature has already had time to turn practically one-

eighth of a revolution and the point of maximum intensity has been passed. While this is a factor of which much is usually made in sales literature, it is not so important as the theory of the matter would make it appear, since the spark is seldom retarded except for starting. With the modern high-speed engine there is rarely sufficient

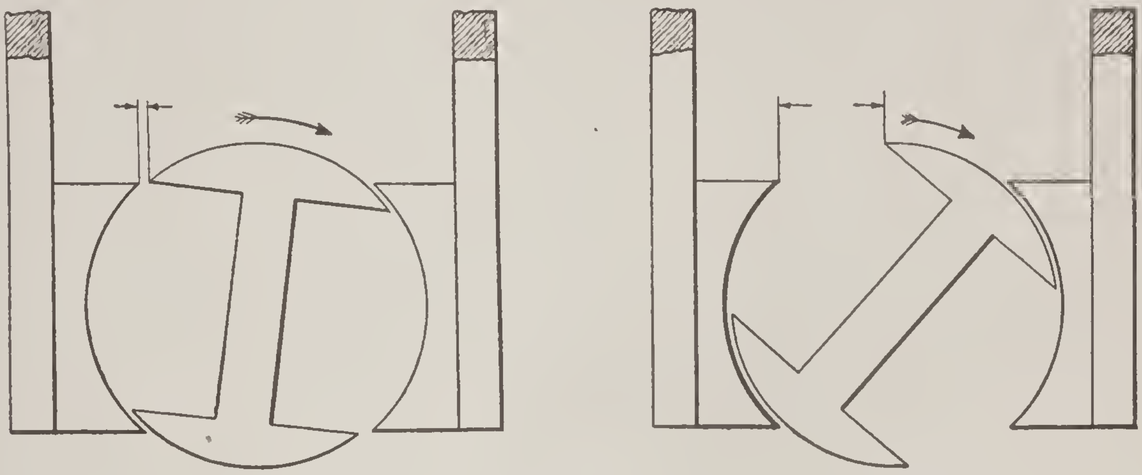


Fig. 93. Position of Magneto Armature for "Advanced" and "Retarded" Ignition

slowing down in hill-climbing to make it necessary to retard the spark, while gear-changing at the proper time further makes this unnecessary, so that practically all the time it is in service, the magneto is operating under the most efficient conditions. The great difference in the positions of the magneto armature between the advanced and the retarded points of the spark timing show why it is difficult to crank a motor by hand with the spark retarded, when relying upon the magneto for ignition.

As already mentioned, most magnetos are fitted with bipolar armatures, i. e., there are two extensions, or pole pieces, between which the winding is placed. This will be clear upon reference to Fig. 94, which shows the armature core of a Simms magneto. The phases are accordingly 180 degrees apart, that is, the current in the armature winding only reaches its maximum value twice per revolution, and as these maxima are really "peaks", as shown by the oscillograph, Fig. 95, there is not much

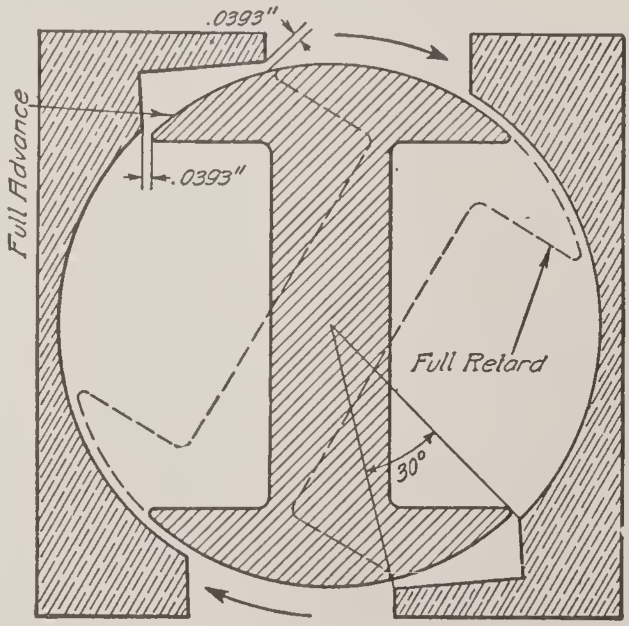


Fig. 94. Section Simms Magneto Armature and Pole Pieces

leeway for variation one way or the other, if the greatest current value is to be utilized.

Analysis of Oscillograph Diagrams. In the oscillograph, the dotted vertical line at the left represents the moment of closing the primary circuit, the current then beginning to increase gradually in value. The resistance of this circuit is such that the current would attain a value of 5 amperes, if the circuit remained closed long enough. However, when the current has attained a value of 4 amperes, the circuit is broken by the vibrator (battery and coil system) and the current then falls off very rapidly. It will be noted that there is no current in the secondary circuit while the primary is attaining its full value, which is due to the fact that the e.m.f.

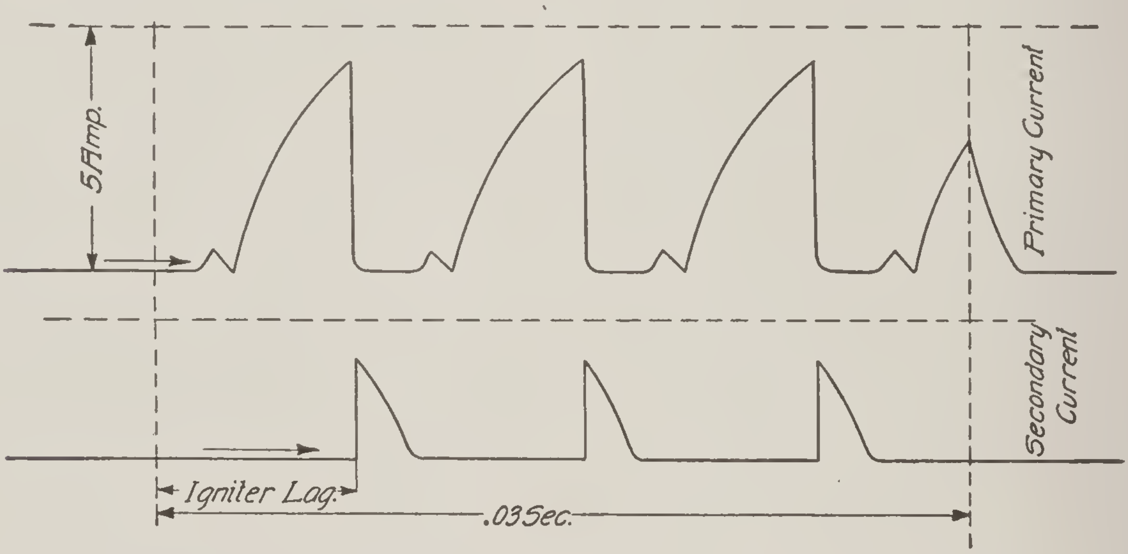


Fig. 95. Oscillograph Diagram of Primary and Secondary Currents
(*Horseless Age*)

induced in the secondary during this period is not sufficient to break down the resistance of the air gap in the spark plug. The spark occurs when the primary circuit is broken, and it is interesting to note that it attains its maximum value instantly, this having been confirmed by numerous oscillograph tests. The right-hand dotted line represents the moment the primary circuit is broken by the timer. With a vibrator coil a series of sparks is produced, as compared with the single spark of the magneto, but these are of no advantage except at low speeds, as when running at full speed, if the first spark fails to ignite the charge, it is already too late by the time the second occurs.

Oscillograph diagrams taken of the current and voltage of a magneto show that both rise to a sharp peak, first in one direction and then in the reverse, as the current is alternating. As the oscillograph illus-

trated shows that only the peak, or maximum, value of the current in the primary of the coil can be utilized for producing a strong induced current in the secondary, so the peak of the magneto current must be taken advantage of to produce the most efficient spark. This point of maximum current value in the revolution of the armature occurs when it is cutting the greatest number of magnetic lines of force of the permanent magnetic field, which is when it is just about to pass from the influence of one set of poles into that of the other, as shown

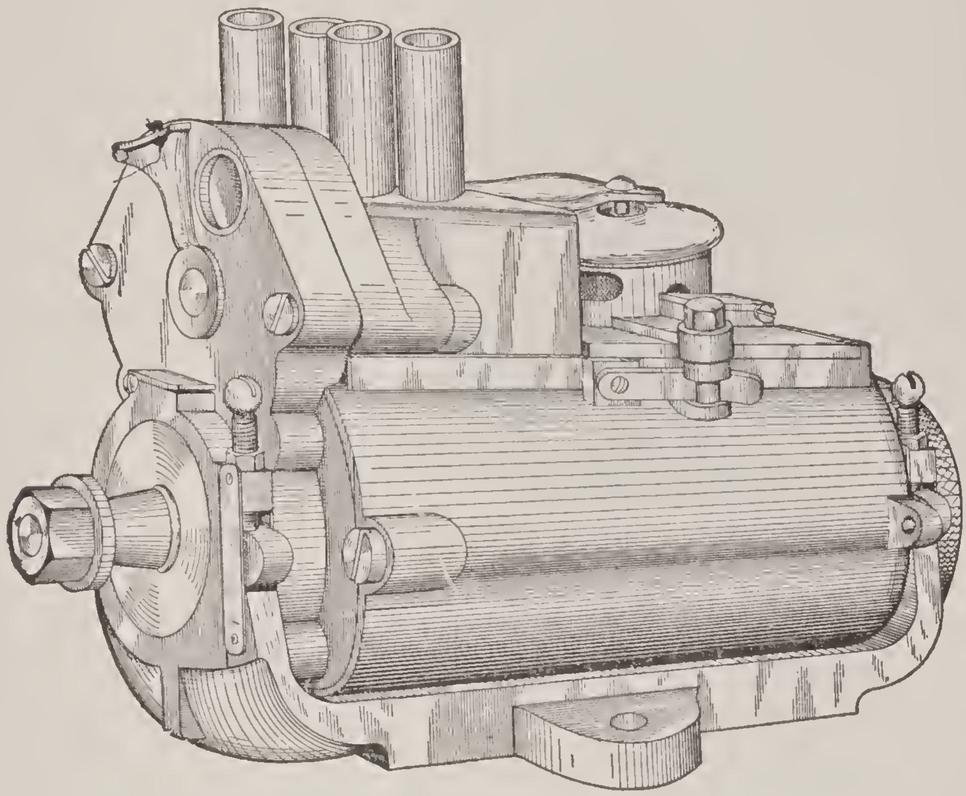


Fig. 96. Mea Magneto in Trunnion Mounting

in the section, Fig. 94. This also shows the relative positions of full advance and full retard and is designed to illustrate the advantages obtained with the patent extended pole pieces of the Simms magneto, most magnetos having the upper and lower faces of both poles in the same plane.

Mea Method of Advancing Spark. Doubtless the most ingenious method of taking care of the necessity for advancing the spark has been developed in the Mea magneto, shown in Fig. 96. Instead of being of horseshoe form, as in the Bosch and Nilmelior magnetos, shown in Figs. 97 and 98, it is bell-shaped, as shown in Fig. 99. The entire magneto is carried in a trunnion mounting so that the field magnets may be turned to the same extent that the contact breaker is moved to give the necessary advance, thus insuring that the circuit will be broken with the armature in the same relative

position to the field poles, which is naturally that of maximum current value.

The method of accomplishing this is shown in Fig. 100, which illustrates the relative positions of the armature and field magnets at the advanced and retarded sparking points to be the same, since the entire magnetic field is partly revolved about the armature. This movement is against the direction of rotation of the armature when advancing the spark, and with it when retarding the timing of the ignition, the illustration showing a magneto arranged to be driven *clockwise.* Fig. 101 illustrates the position of the fields when looking at the driven end of the magneto for advanced and retarded spark in both the clockwise and *anti-clockwise* types. The range of timing varies from 55 degrees to 70 degrees in the various models; and a specially long range totaling 90 degrees to 100 degrees can be provided, if necessary, by increasing the overall height of the magneto, as the shaft must be supported higher in the trunnions to permit of this. Among the advantages of this method of ignition timing are ease of starting without a battery, quick acceleration, and a uniformly efficient spark at all positions of the sparking lever.

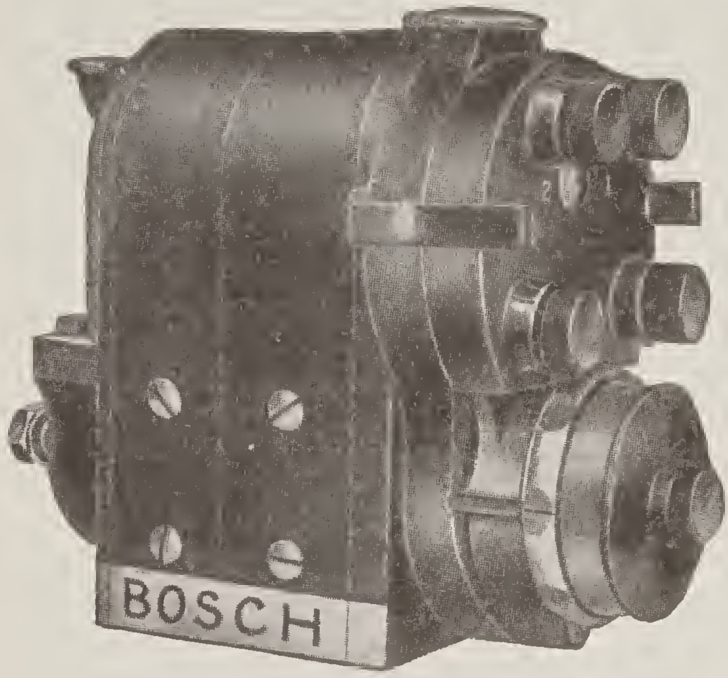


Fig. 97. Bosch Enclosed Type Magneto

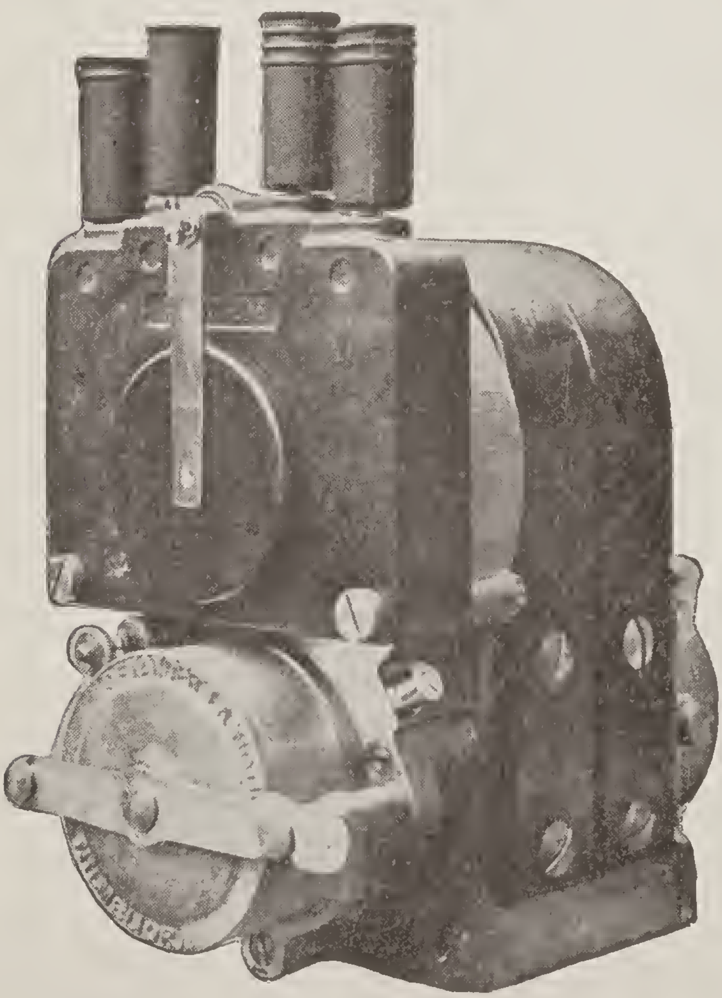


Fig. 98. Front View Nilmelior Magneto

Magneto Speeds. As the revolution of the armature of the magneto always bears a definitely fixed relation to that of the crankshaft of the engine, it will be apparent that the speed at which the magneto is driven will depend upon the number of cylinders to be fired, as well as upon the relation of the cylinders to one another, i.e., firing 180 degrees or 360 degrees a part, as measured on the crankshaft. The following are the various magneto speeds required for engines of the four-cycle type having from one to twelve cylinders:

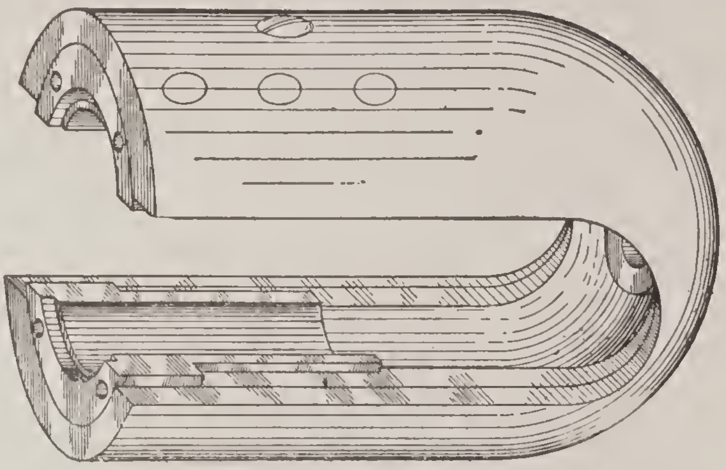


Fig. 99. Bell-Shaped Magnets of Mea Magneto

1-cylinder: Either crankshaft or camshaft speed
2-cylinder: (Impulses 360° apart, as in 2-cylinder opposed motor) camshaft speed
2-cylinder: (Impulses alternately at 180°, with 540° intervals, as in the 2-cylinder V-type motor) camshaft speed
3-cylinder: Three-fourths crankshaft speed
4-cylinder: Crankshaft speed
6-cylinder: One and one-half times crankshaft speed
8-cylinder: Twice crankshaft speed
12-cylinder: Three times crankshaft speed

Owing to the extremely high speeds necessary, the modern battery type of ignition is favored to a great extent on eight- and

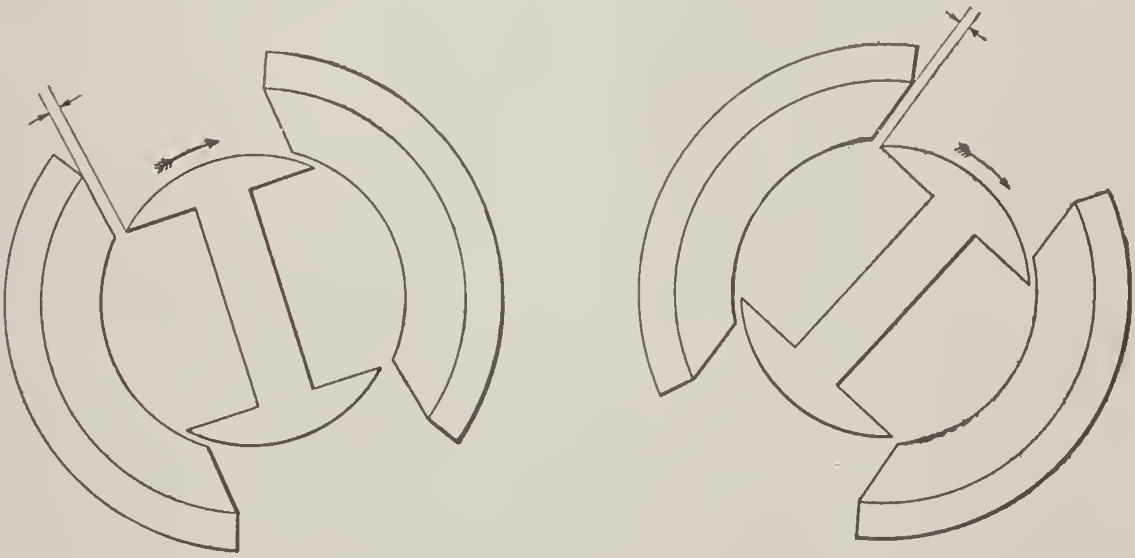


Fig. 100. Relative Position of Armature and Magnets at Moment of Sparking, in Mea Magneto

twelve-cylinder motors, though magnetos are built even for the latter. (See description Splitdorf 12-cylinder magneto.)

The magneto speeds necessary on two-cycle motors are twice those given above for the corresponding four-cycle types, with the exception that, on the 2-cylinder 180-degree or V-type motor, crank-shaft speed would be correct.

Ignition=System Fixed Timing Point. It has become more or less general practice with French builders to provide an ignition system having a fixed timing point, i.e., one that cannot be controlled by the driver through the usual spark-advance lever as found on practically all American pleasure cars. This is particularly the

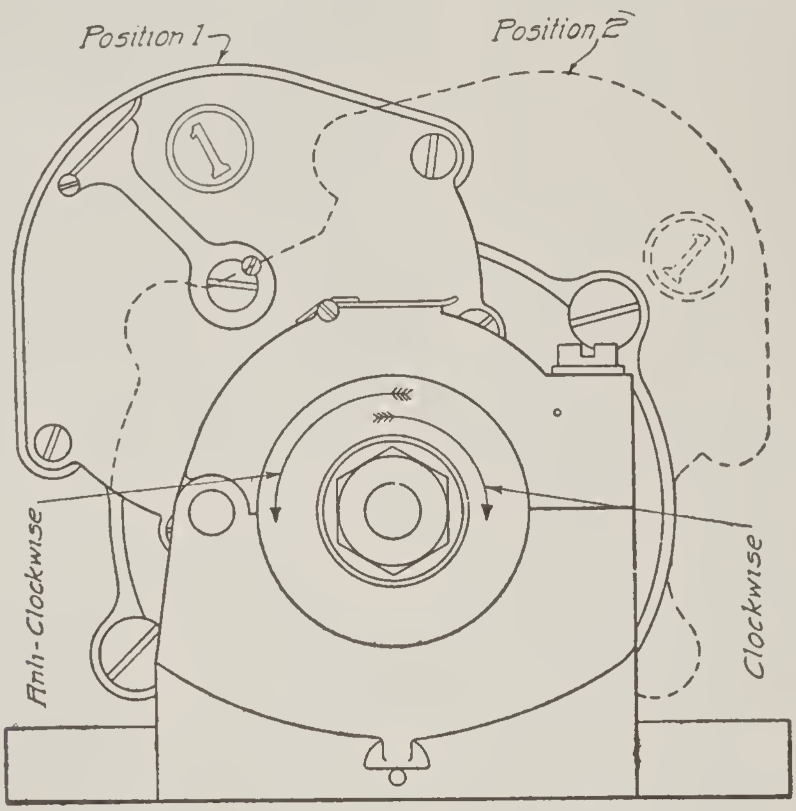


Fig. 101. Spark Advance with Meo Magneto. With Clockwise Instruments, Position 1 Supplies Advanced Spark, Position 2 Retarded Spark

case with taxicabs. While "fixed" in the sense that they are not variable while running, such systems have two firing points, one of maximum advance, which is always employed when the motor is in operation, and the other of maximum retard to enable the driver to crank the motor without danger of injury. So-called fixed-spark ignition systems have come into very general use abroad, more especially on the Continent, but have found very little favor here.

Automatically Timed Systems. The stress laid by automobile manufacturers on their instructions, "always retard the spark before cranking the motor" and "always run with the spark advanced as far as possible, except when necessary to retard it owing to the motor slowing down on hills and causing a hammering noise in the cylinders",

make it evident that there is a considerable amount of discretion left in the driver's hands where this important point is concerned. It is

Fig. 102. Armature with Centrifugal Timing Device, Eisemann Magneto

not desirable that this should be exercised by unskilled drivers, particularly those in charge of large and costly commercial vehicles, and automatically timed systems have accordingly been developed.

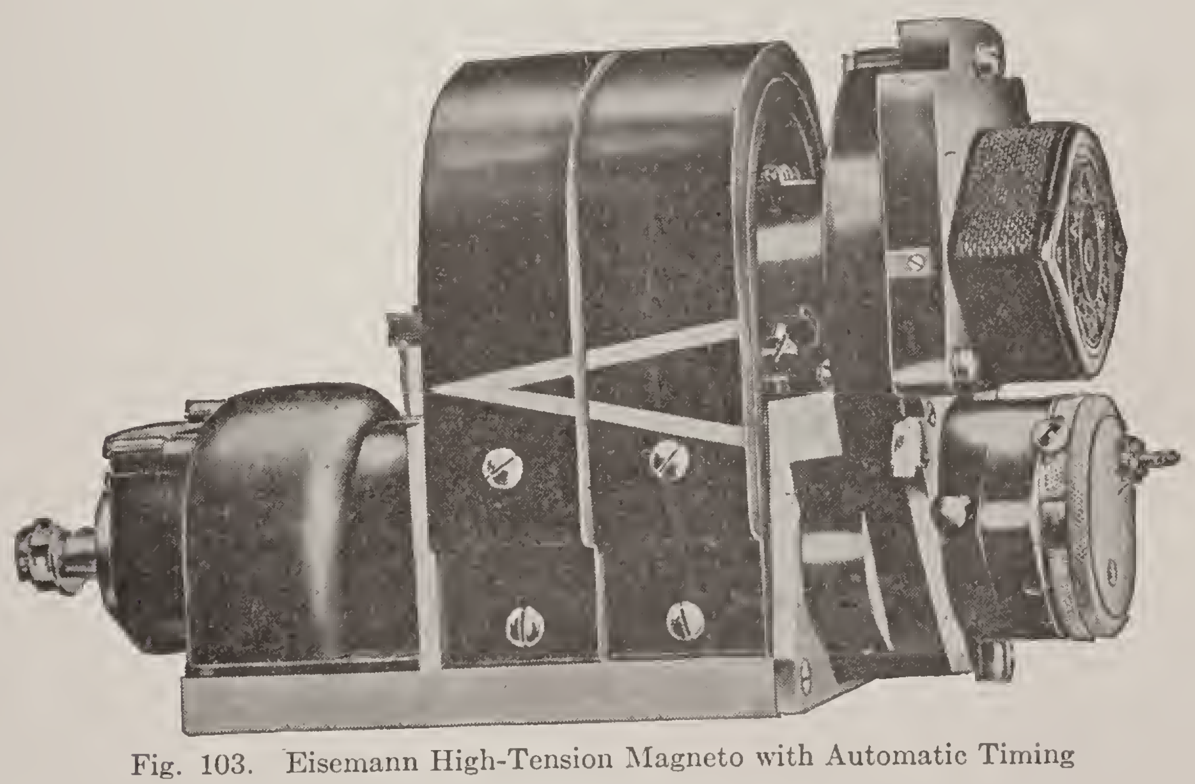


Fig. 103. Eisemann High-Tension Magneto with Automatic Timing

Eisemann Centrifugal-Governor Type. To advance the spark timing automatically, a centrifugal governor has been mounted on

the armature shaft in the Eisemann magneto of this type, as shown in Fig. 102. Normally, the weights are contracted by the spring and the contact breaker is held at the fully retarded position, so that it is always safe to crank the motor without the necessity of taking any precautions. With an increase in speed, these weights tend to fly apart and in doing so they draw a sleeve and with it the armature along the shaft with them toward the left-hand end. As there are two helicoidal ridges on the shaft, however, and splines on the inner diameter of the sleeve engaging them, the sleeve is forced to make a partial revolution as it moves along the shaft, thus automatically advancing the ignition timing in accordance with the speed. The contact breaker is in fixed relation to the armature. An Eisemann magneto fitted with the automatic timing device is shown in Fig. 103. The lines drawn on the magnets indicate their polarity, so that in case the machine is taken apart it can readily be assembled again with the magnets in their proper relation.

Fig. 104. Herz Automatic Spark Advance Coupling

Fig. 105. Herz Automatic Coupling (Side View)

Herz Ball-Governor Type. Another method of accomplishing the same end is the Herz automatic coupling, shown in Figs. 104 and 105. This consists of two juxtaposed disks, each of which is provided with five grooves running in a direction opposite to those of the other disk. Five steel balls are held in these grooves and act like the weights of a governor, being forced outward in direct proportion to the speed of the motor, thus imparting a twisting movement to the magneto armature with relation to its shaft. The device is supplied either as an integral part of the magneto or as an independent coupling. The range of movement is 40 degrees, the adjustment being varied by altering the curve of the grooves. Fig. 106 shows the Herz magneto. In the Eisemann, spindles having grooved slots of several different pitches are supplied, giving from 19 to 60 degrees of advance. The Atwater Kent, Connecticut, and Westinghouse ignition systems may also be had with automatic advance operated by a centrifugal governor.

Ignition Setting Point. It will be apparent that as provision is made for advancing the time of ignition beyond a certain point as well as retarding it so as to occur before that point, there must be what may be termed a neutral position. This is usually referred to as the ignition setting point. In the majority of instances, this is the upper dead center, particularly where a magneto is employed. For the reason that it is possible to start the motor by handcranking on the magneto with the time of ignition advanced very much farther than would be safe with a battery, as explained in another

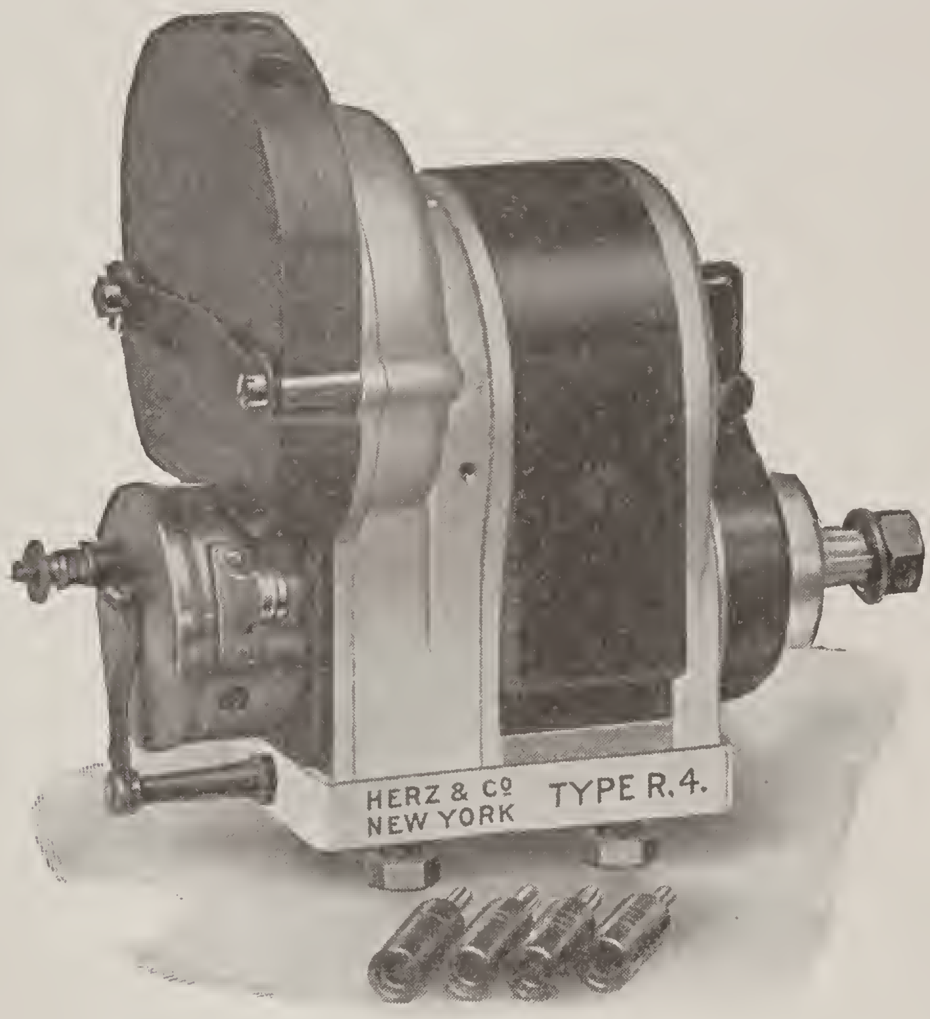


Fig. 106. Herz Magneto

section, it is seldom necessary to provide for retarding the ignition timing of a magneto past upper dead center. Consequently, the ignition setting point for the majority of magnetos is upper dead center when the spark-advance lever on the quadrant is at the point of maximum retard. It is not necessary to provide for what is termed a *late* spark, i.e., one occurring after the piston has actually started down on the power stroke, nor is it necessary to provide as great a range of advance in the case of the magneto as where a battery is employed, since the magneto, to a certain extent, automatically advances the moment of ignition as the speed increases.

Where a battery is employed, however, it is customary to allow a greater range of timing in both directions with a *late* spark to insure safety in starting, particularly by handcranking. The relation of the ignition distributor of a battery system to the crankshaft is shown in Fig. 107, which illustrates the ignition diagram of the four-cylinder Regal Motor. The firing order in this case is 1-2-3-4, and it will be noted that the ignition setting point is upper dead center.

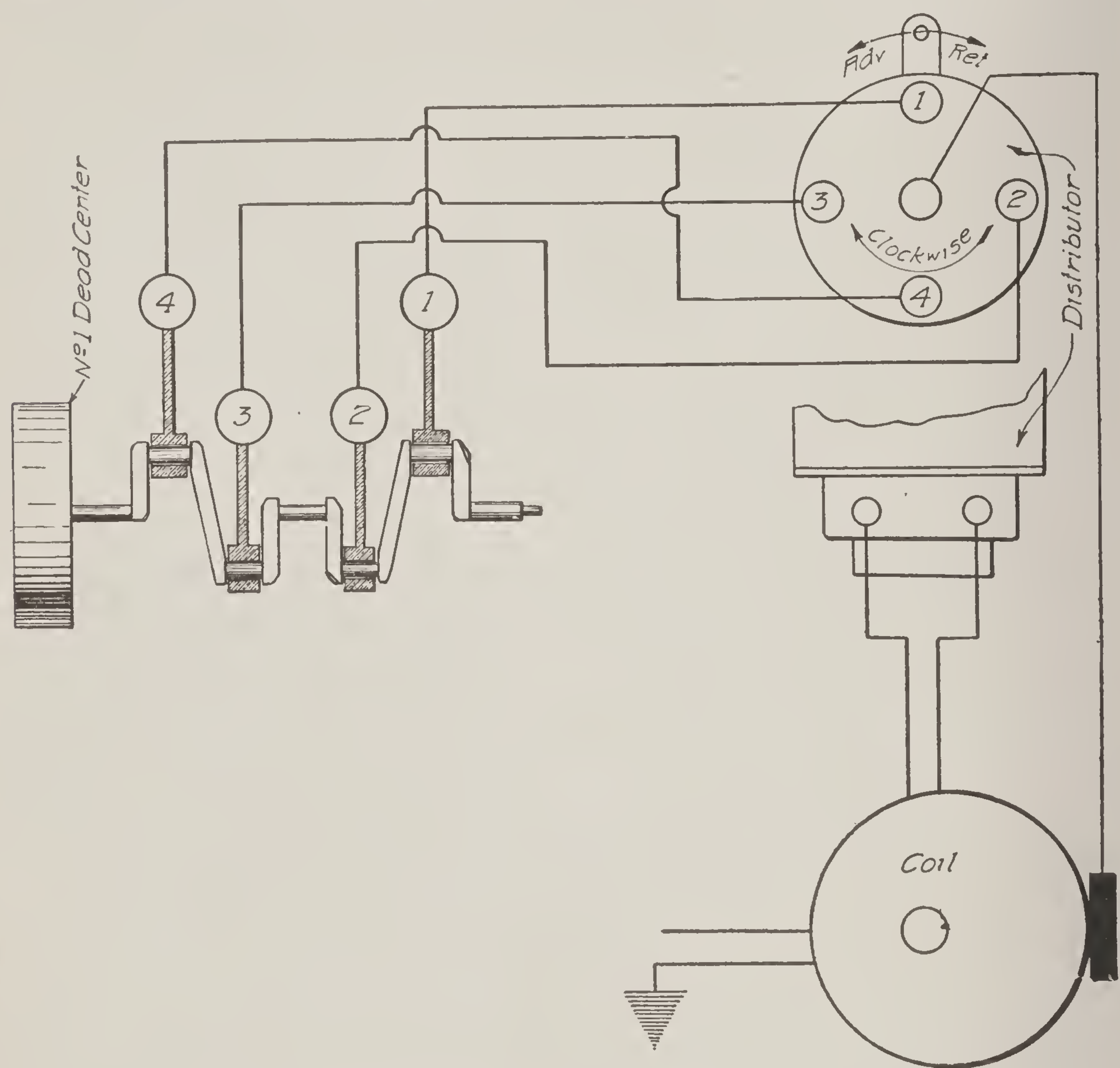


Fig. 107. Relation of Ignition Distributor to Engine Crankshaft.
Courtesy of Regal Motor Car Company, Detroit, Michigan

Both the ignition and the valve timing of practically all motors built in recent years may be checked by marks on the flywheel. A corresponding mark or pointer on the crankcase is used as a checking point.

Fig. 107 shows that when piston No. 1 is exactly at upper dead center, contact No. 1 of the distributor is under the brush leading to the spark plug of that cylinder, and, as shown by the center line, this is the ignition setting point for that motor. As the distributor

turns in a clockwise direction, rotating it toward the right, as shown in the diagram, retards the time of ignition, while turning it to the left advances it. The interrupter is just below the distributor and while its battery, ground, and distributor cables are shown, the contacts themselves are not illustrated.

Upper Dead Center. In many cases it is no longer possible to check the ignition timing or the position of the pistons by the flywheel, as the latter is entirely enclosed. To find the upper dead center of the piston of the first cylinder it is accordingly customary to take out a spark plug and use a long knitting needle or similar piece of straight wire. While an assistant turns the motor over slowly by hand, watch the valves of cylinder No. 1. When the inlet valve of this cylinder has closed, the piston is traveling upward on the compression stroke and the needle will rise. It must be borne in mind, however, that the piston is not actually at upper dead center for ignition purposes when the needle ceases rising. In other words, a certain part of the revolution of the crank is not represented by a corresponding movement of the piston, and the proportion that this bears to the whole revolution naturally increases with the length of the stroke.

The starting crank should accordingly be turned until the needle actually starts downward again on the firing stroke, and then the motor turned backward again slightly until it ceases to rise. This may be done by putting the gear lever in *high*, engaging the clutch, jacking up one rear wheel and turning it backward. This will give the proper ignition setting point for any system in which this point is given as "upper dead center with the spark at the point of maximum retard". But unless the precaution in question is taken, the spark timing will have a slight amount of advance and, in a long-stroke motor using a battery system of ignition, this may be sufficient to cause the motor to kick back when cranked slowly by hand.

In some cases, where the flywheel rim is not accessible, the ignition setting point is marked on the distributor itself.

FIRING ORDER

Typical Firing Orders. It is naturally quite as important that the sparks occur in the different cylinders of a multi-cylinder motor in the proper order as that each individual spark should take place

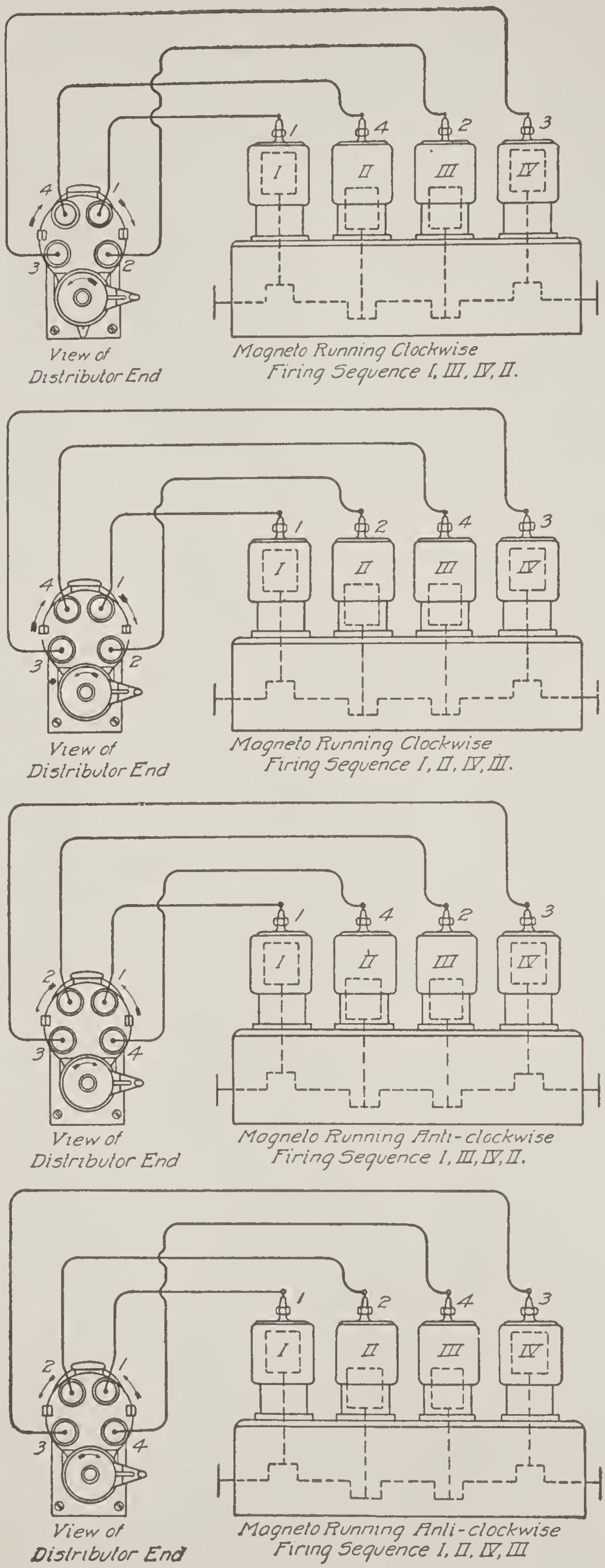


Fig. 108. Firing Order of Four-Cylinder Motors
(*Bosch Magneto Company*)

at just the right moment. Regardless of the number of cylinders, the crankshaft throws are always in pairs. Hence, the pistons rise and fall in pairs, and the cylinders of these pairs (which have no relation whatever to the method of casting the cylinders themselves) naturally cannot follow each other in firing, the firing order alternating from one pair to the other. For example, 1- 3- 4- 2- as in the upper diagram of Fig. 108, or 1- 2- 4- 3- as in the diagram just below it, the motors in both these instances running "clockwise", i.e., with the crankshaft turning from left to right. A similar variation is possible with the motor turning "anti-clockwise", or from right to left, as shown in the two lower diagrams, which show firing orders of 1- 3- 4- 2- and 1- 2- 4- 3- the changes being made by shifting the distributor connections to the spark plugs of the various cylinders. In the case of a high-tension battery system using unit coils, the timer connections are

varied in the same manner. In six-cylinder motors the crank throws are 120 degrees apart, but as the pistons are attached in pairs to cranks in the same plane, the method of distributing the firing order among them is similar to that already given. The Bosch dual ignition system, as installed on the six-cylinder Winton, is a typical firing order for a six. As shown by Fig. 109, this runs 1- 5- 3- 6- 2- 4.

Possible Combinations. There are so many possible firing orders in the six-cylinder motor and likewise in the more recent eight-cylinder and twelve-cylinder motors that one of the most puzzling questions arising in the repair shop frequently has been to determine just which one has been adopted by the manufac-

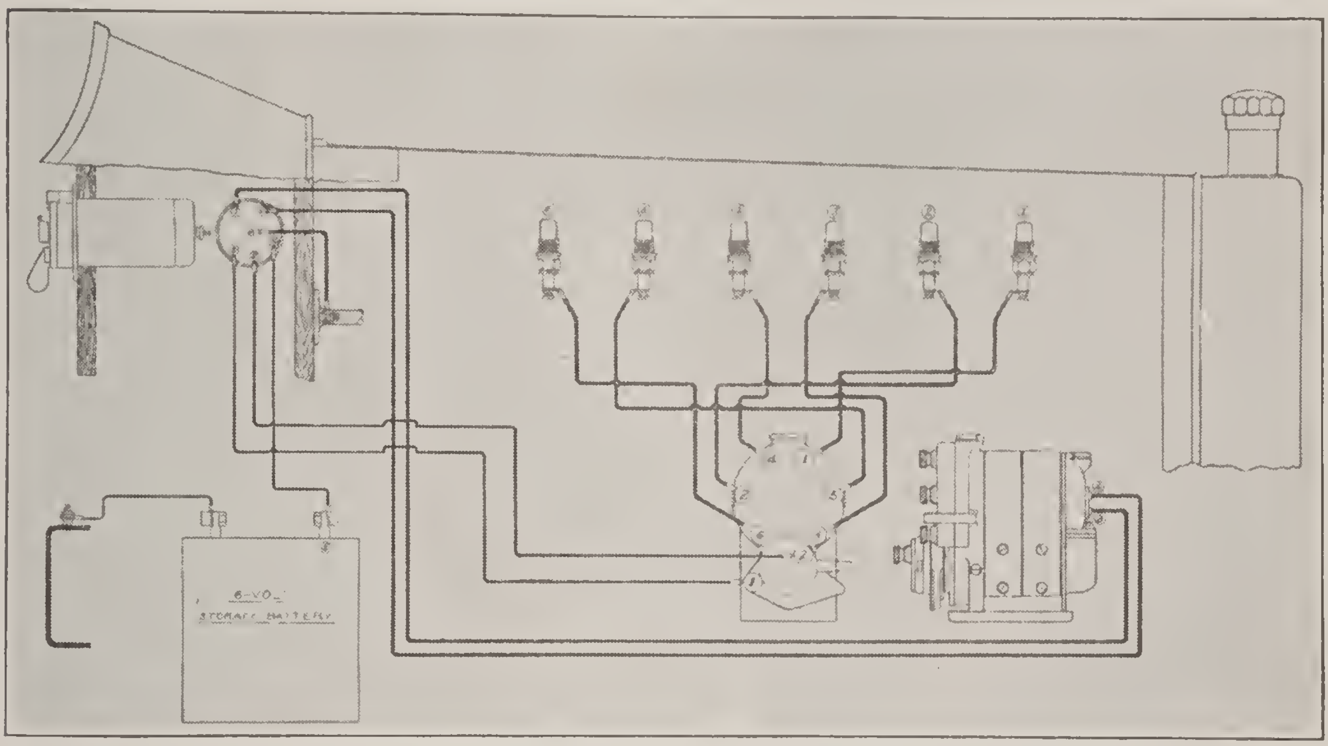


Fig. 109. Firing Order of Six-Cylinder Winton Motor

turer for his particular motor. So much uncertainty exists that many makers have solved this for the repair man by attaching a plate to the motor or to the dash, giving the firing order. There are eight firing orders possible for the six or eight. With the six these are:

(a) 1 2 3 6 5 4	(e) 1 4 5 6 3 2
(b) 1 2 4 6 5 3	(f) 1 5 4 6 2 3
(c) 1 3 2 6 4 5	**(g) 1 4 2 6 3 5**
(d) 1 3 5 6 4 2	**(h) 1 5 3 6 2 4**

While any of these firing orders will give an equally good impulse balance, the question of proper distribution of the incoming charge and the free escape of the exhaust also have an important bearing on the matter, so that the last two orders given are in most general use. The Winton Six, Fig. 109, shows the employment of order (**h**).

For the V-type eight-cylinder motor, the possible firing orders are as follows:

(i) 1R 1L 2R 2L 4R 4L 3R 3L
(j) 1R 1L 3R 3L 4R 4L 2R 2L
(k) 1R 4L 2R 3L 4R 1L 3R 2L
(l) **1R 4L 3R 2L 4R 1L 2R 3L**
(m) 1R 1L 3R 2L 4R 4L 2R 3L
(n) 1R 1L 2R 3L 4R 4L 3R 2L
(o) 1R 4L 2R 3L 4R 1L 3R 3L
(p) 1R 4L 2R 3L 4R 1L 2R 2L

As the last four mentioned involve different firing orders in each set of four cylinders, they need not be considered. With the

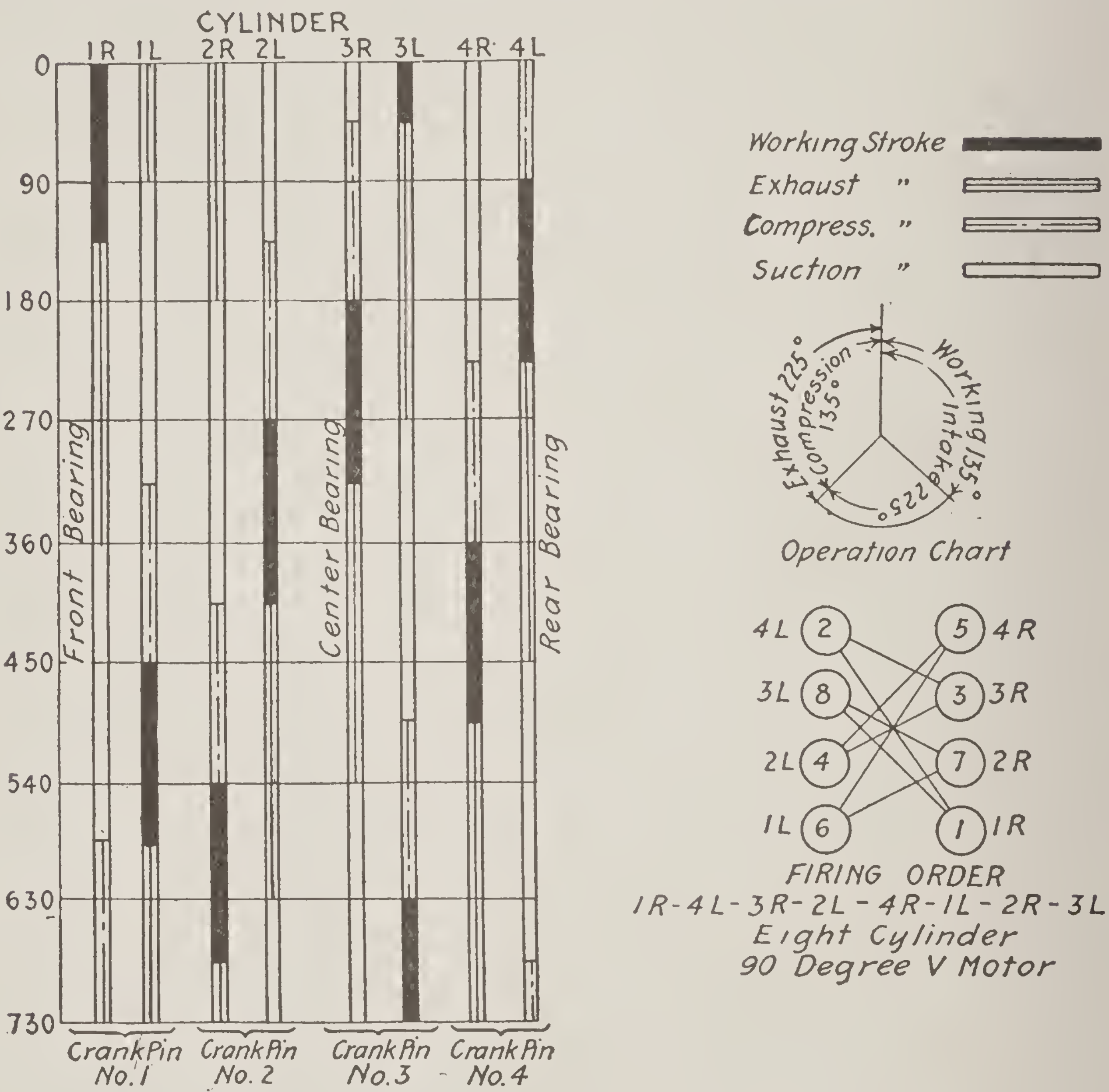


Fig. 110. Firing Order of Eight-Cylinder, V-Type Motor
Courtesy of "Automobile Topics", New York City

rocker-arm type of valve lifters using only eight cams, as in the De Dion (French, and the first to use an eight-cylinder motor), Cadillac, and King engines, it is only possible to use the orders k and l, while, as a matter of fact, all three employ the order given in l, which is shown diagrammatically in Fig. 110. The other possible order for an eight (k) may be read from the same diagram by turning it around and changing the numbers from 4L to 1R, 3L to 2R,

and so on. A curious fact is that in each of these orders the sum of the numbers of two cylinders which fire in succession is always 5. By starting always with a right-hand cylinder, the firing order can readily be determined by noting whether the firing order in one of the groups of four cylinders is 1- 3- 4- 2 or 1- 2- 4- 3.

Just as the eight-cylinder V-type motor is simply a combination of two groups of four cylinders, each of which considered alone would have the standard firing order of a four, so the twelve-cylinder V-motor is simply the bringing together on one crankshaft of two six-cylinder motors. The firing order adopted is accordingly one of the two preferred for the six-cylinder motor (**g** and **h**), alternating from the right-hand to the left-hand group in the same manner as shown for the eight-cylinder motor.

Firing Orders and Ignition Advance. Repairs and adjustments to the ignition system of a motor are always much easier to carry out when the characteristics of the system in question are known. For this reason the firing orders of the various models of different makes, together with the setting point and the amount of advance and retard, are given here for practically all makes of cars. Whereever it could be obtained, this information is given for all models of every make for the past five years, but in some instances it was not available. The information is given in the alphabetical order of the makers' names to make reference easy.

Allen

1917 Fours. Firing order 1- 2- 4- 3.

Battery ignition; extreme retard, dead center; maximum advance 30°.

Apperson

1914–15 Fours. F.O. 1- 3- 4- 2.

1915–16–17 Sixes. F.O. 1- 5- 3- 6- 2- 4.

1916–17 Eights. F.O. 1R- 4L- 3R- 2L- 4R- 1L- 2R- 3L.

Extreme retard, dead center; maximum advance 15°.

Auburn

Sixes. Models Six-45, Six-46, and Six-47.

F.O. 1- 4- 2- 6- 3- 5.

Models Six-40, Six-40A, Six-44, Six-38, and Six-39.

F.O. 1- 5- 3- 6- 2- 4.

Most of the above models are equipped with battery ignition.

Austin

Twelves. F.O. 1R- 1L- 4R- 4L- 3R- 3L- 6R- 6L- 2R- 2L- 5R- 5L.

Delco system.

Biddle

Fours. F.O. 1- 3- 4- 2.

Magneto setting; full retard, upper dead center.

Bour=Davis

Sixes. F.O. 1- 5- 3- 6- 2- 4.

Brewster

Fours. F.O. 1- 3- 4- 2.

Magneto setting; maximum advance when piston is 5 mm. (practically $\frac{1}{5}$ inch) below upper dead center.

Briscoe

Fours. F.O. 1- 3- 4- 2.

Eights. F.O. 1R- 1L- 3R- 3L- 4R- 4L- 2R- 2L.

Ignition setting; upper dead center; maximum advance 15°.

Buick

1913 Fours. F.O. 1- 3- 4- 2.

Remy Model, RL magneto; extreme retard, dead center; maximum advance about 30°.

1914–16 Fours. F.O. 1- 3- 4- 2.

Sixes. F.O. 1- 4- 2- 6- 3- 5.

All models since 1913 Delco battery-ignition system; extreme retard, 7° beyond dead center, except on Models B-24-5 and 36-7, on which 40° retard is provided, owing to the excessive amount of advance provided in the distributor assembly; maximum hand advance 50° to 72°. Models D-44-5, D-54-55, C-54-55, 15° automatic advance. Models C-36-37 and C-4, automatic advance 24° 32′.

Case

1914–15–16–17 Fours. F.O. 1- 3- 4- 2.

Extreme retard, dead center; maximum advance 30°.

Chadwick

Sixes. F.O. 1- 3- 2- 6- 4- 5.

Chalmers

1912–13–14 Fours. F.O. 1- 3- 4- 2.

Magneto setting; extreme retard, dead center; advance not given.

1914 Sixes. F.O. 1- 4- 2- 6- 3- 5.

Magneto setting; extreme retard, dead center; advance 1½ inches on flywheel.

1915 Sixes. F.O. 1- 4- 2- 6- 3- 5.

Atwater Kent battery system; extreme retard, 1½ inches on flywheel.

1915 Sixes. F.O. 1- 4- 2- 6- 3- 5.

Magneto setting; extreme retard, dead center.

1916 Sixes. F.O. 1- 4- 2- 6- 3- 5.

Atwater Kent battery system; extreme retard, dead center.

1916 Sixes. Model 35. F.O. 1- 4- 2- 6- 3- 5.

Remy magneto setting; extreme retard, dead center.

Chandler

All Models. F.O. 1- 5- 3- 6- 2- 4.

Magneto; extreme retard; interrupter opens at top dead center; this is when back edge of magneto armature is central between pole pieces; maximum advance 30° to 35° at the magneto or 20° to 25° at the crankshaft.

Chevrolet

1912–17 Fours. F.O. 1- 2- 4- 3.

Sixes. F.O. 1- 4- 2- 6- 3- 5.

Eights. F.O. 1L- 3R- 2L- 1R- 4L- 2R- 3L- 4R.

Chicago

Sixes. F.O. 1- 5- 3- 6- 2- 4.

Battery ignition setting; extreme retard, upper dead center.

Coey

Fours. F.O. 1- 3- 4- 2.

Sixes. F.O. 1- 4- 2- 6- 3- 5.

Cole

1912–14–15 Sixes. F.O. 1- 5- 3- 6- 2- 4.

1912–13 Fours. F.O. 1- 3- 4- 2.

1916–17 Eights. F.O. 1- 8- 3- 6- 4- 5- 2- 7.

Battery ignition on all later models.

De Dion

Fours. F.O. 1- 3- 4- 2.

Eights. 1R- 4L- 3R- 2L- 4R- 1L- 2R- 3L.

Magneto fixed ignition; setting point, 6 to 10 mm. before upper dead center.

Dixie

Four. F.O. 1- 3- 4- 2.

Dodge

All Models. F.O. 1- 3- 4- 2.

Eisemann magneto; setting point at extreme retard, 5° in advance top dead center; maximum advance 30°.

Dorris

Fours. F.O. 1- 3- 4- 2.

Magneto set to fire at upper dead center when fully retarded.

Sixes. F.O. 1- 5- 3- 6- 2- 4.

Same setting; maximum advance 35°.

Dort

All Models. F.O. 1- 3- 4- 2.

Battery ignition system.

Elkhart

Fours. F.O. 1- 3- 4- 2.

Empire

Model 31. F.O. 1- 2- 4- 3.

On motors with chain-driven camshaft. Magneto; fixed ignition point 17° in advance of dead center.

Model 31. F.O. 2- 1- 3- 4.

On motors having a gear-driven camshaft.

Models 33 and 31–40. F.O. 1- 2- 4- 3.

Battery ignition with Remy distributor; extreme retard, upper dead center.

Models 40, 45, and 50. F.O. 2- 1- 3- 4.

Battery ignition.

Models 60 and 70. F.O. 1- 5- 3- 6- 2- 4.

Battery ignition; extreme retard, upper dead center.

Enger

Sixes. F.O. 1- 5- 3- 6- 2- 4.

Twelves. F.O. 1R- 1L- 5R- 5L- 3R- 3L- 6R- 6L- 2R- 2L- 4R- 2L.

Battery ignition. It will be noted that this is exactly the same as the firing order of the sixes, except that the order alternates from one group to the other; this is true of most eight-cylinder and twelve-cylinder motors; that is, the firing order is equivalent to that of two alternate fours or sixes.

Erie

Fours. F.O. 1- 2- 4- 3.

Fiat

Fours. F.O. 1- 3- 4- 2.

Sixes. F.O. 1- 4- 2- 6- 3- 5.

Ford

Fours. All Fours since 1906. F.O. 1- 2- 4- 3.

Sixes. Built about 1905 or 1906. F.O. 1- 2- 3- 6- 5- 4.

The Ford magneto is not timed to the engine; owing to the large number of poles and armature coils, it delivers a constant current (alternating) which is timed by the commutator, or timer, in the same manner as with a battery source of supply.

Franklin

Sixes. F.O. 1- 4- 2- 6- 3- 5.

Magneto setting point measured on rim of flywheel, 1½ inches for Franklin series 5, 6, 7, and 8 motors; 2½ inches for series 9 motor. In the series 5–8, inclusive, the flywheel is 18 inches in diameter, while in series 9 it is 17 inches. Maximum advance series 5–8, 7½ inches on flywheel; series 9, 7 inches.

F. R. P.

Fours. F.O. 1- 2- 4- 3.

Contact points of magneto open when magneto armature is ⅝ inch from pole piece, piston being at upper dead center. This gives spark at approximately dead center, with full retard. Advance is maximum afforded by magneto used.

Glide

Fours. F.O. 1- 3- 4- 2.

Sixes. F.O. 1- 5- 3- 6- 2- 4.

Magneto setting; extreme retard, upper dead center.

Grant

Fours. F.O. 1- 2- 4- 3.

Sixes. F.O. 1- 4- 2- 6- 3- 5.

Hollier

Sixes. F.O. 1- 4- 2- 6- 3- 5.

Eights. F.O. 1- 6- 3- 5- 4- 7- 2- 8.

Battery ignition, Remy system on the six-cylinder model

and Atwater Kent on the eight-cylinder. Ignition setting; extreme retard, upper dead center; maximum advance approximately 15°.

Homer-Laughlin

1916 Eights. F.O. 1- 8- 3- 6- 4- 5- 2- 7.

1917 Eights. F.O. 1- 6- 3- 5- 4- 7- 2- 8.

Magneto setting point approximately 5° after piston passes upper dead center; maximum advance about 30°.

Hudson

Sixes. F.O. 1- 5- 3- 6- 2- 4.

The following instructions for ignition setting as applied to the Delco ignition system used on the Hudson cars are also applicable, with slight modifications, to practically all cars using this system, although the amount of advance will naturally differ in many cases. First, remove the distributor head and measure the gap between the distributor contacts. This should be done when they are opened to the maximum. The gap should be set at .012 to .018 inch, using the feeler gage on the Delco distributor wrench provided for this purpose. Set the spark lever at the top of the quadrant or in the fully advanced position; open all the priming cocks. When No. 1 cylinder blows air out of its priming cock, its piston is rising on the compression stroke.

On Model Six-40, 1914, No. 1 cylinder is due to fire in the advanced position when the line *A* on the flywheel reaches the pointer attached to the crankcase. This may be observed through the inspection hole on the flywheel housing on the left side of the motor. This line *A* is $2\frac{3}{4}$ inches before dead center for cylinders Nos. 1 and 6. The 1915–16 Six-40 Models are due to fire on No. 1 cylinder $\frac{1}{2}$ inch before dead center; 1914–16 Model 54, 6 inches before dead center; 1916 Super Six, $\frac{5}{8}$ inch before dead center, the setting in each case being checked by bringing the line *A* on the flywheel directly opposite the pointer.

After the piston of No. 1 cylinder has been brought to the proper position, loosen the cam on the distributor shaft by turning out the set screw in the center of the shaft. Set the distributor so that when the contacts are just opening, the button on the rotor comes under No. 1 on the distributor head. The spark occurs the instant the contacts separate. In checking the timing, the cam should be held

in tension against its direction of rotation, which is *clockwise*, so that all play, or *blacklash*, will be taken up. The set screw must always be screwed home tight after checking or making an adjustment, to prevent its slipping. The rotor should now be replaced on the distributor shaft, first rubbing a slight amount of vaseline on the rotor track with the finger, and the distributor head put back in position tightly.

Hupp

Up to 1912. Model 20. F.O. 1- 2- 4- 3.

Bosch high-tension magneto; fixed firing point.

Up to 1915. Model 32. F.O. 1- 2- 4- 3.

Magneto; manual advance.

Models K and N. F.O. 1- 2- 4- 3.

Atwater Kent; manual and automatic spark advance.

1911–12. F.O. 1- 3- 4- 2.

Magneto; extreme retard, upper dead center; advance 37½°.

Interstate

1915–17. Model T. F.O. 1- 2- 4- 3.

Magneto setting; extreme retard, upper dead center; maximum advance 20°.

1914–15. Model 45. F.O. 1- 5- 3- 6- 2- 4.

Extreme retard, upper dead center; maximum advance 37½°.

Jackson

1917. Model 349. F.O. R1- L1- R3- L3- R4- L4- R2- L2.

Jeffery

1913 Fours. F.O. 1- 2- 4- 3.

1914 Fours. F.O. 1- 3- 4- 2.

Advance 35°.

1915 Fours. F.O. 1- 3- 4- 2.

Advance 35°.

1915 Sixes. Model 104. F.O. 1- 5- 3- 6- 4- 2.

Advance 22½°.

Sixes. Model 106. F.O. 1- 4- 2- 6- 3- 5.

Advance 22½°.

1916 Sixes. Model 96. F.O. 1- 4- 2- 6- 3- 5.

Advance 22½°.

Sixes. Model 661. F.O. 1- 5- 3- 6- 2- 4.

Advance 24°.

Fours. Models 462 and 472. F.O. 1- 3- 4- 2.
Advance 28°.
1917 Sixes. F.O. 1- 5- 3- 6- 4- 2.
Advance 28°.
Fours. F.O. 1- 3- 4- 2.
Advance 28°. Magneto setting point all models; spark lever full retard, dead center.

King

1913–14 Fours. F.O. 1- 3- 4- 2.
1915–16 Eights. F.O. 1L- 8R- 3L- 6R- 4L- 5R- 2L- 7R.
Battery ignition; automatic spark advance; extreme retard, upper dead center; advance increases automatically with speed of motor.

Kisselkar

Fours. F.O. 1- 3- 4- 2.
Sixes. Models F11, G9, and G10, 1912–15, Six-60 and Six-48. F.O. 1- 4- 2- 6- 3- 5.
Model Six-42 and Hundred Point Six. F.O. 1- 5- 3- 6- 2- 4.

Kline

Fours. F.O. 1- 2- 4- 3.
Up to and including 1914 Sixes. F.O. 1- 4- 2- 6- 3- 5.
1915–17 Sixes. F.O. 1- 5- 3- 6- 2- 4.

Lexington-Howard

1908–12 Fours. F.O. 1- 3- 4- 2.
1914–15 Fours. F.O. 1- 3- 4- 2.
1913–14 Sixes. F.O. 1- 5- 3- 6- 2- 4.
1915–17 Sixes. F.O. 1- 5- 3- 6- 2- 4.
Setting point with full retard, dead center.

Liberty

Sixes. F.O. 1- 5- 3- 6- 2- 4.
Distributor set 1 inch late.

Locomobile

1910–12 Fours. F.O. 1- 2- 4- 3.
1913 Sixes. F.O. 1- 5- 3- 6- 2- 4.
The armature shaft of the magneto is set so that the H-shaped core is 14 millimeters, or .551 inch, from the pole piece of the magneto for Model 30 and 21 millimeters, or .827 inch, for Models 38 and 48.

1914–15 Sixes. F.O. 1- 5- 3- 6- 2- 4.

The armature shaft of the magneto is set so that the H-shaped core is 21 millimeters, or .827 inch, from the pole piece of the magneto in Model 38 and 25 millimeters, or .985 inch, for Model 48.

1916–17. F.O. 1- 5- 3- 6- 2- 4.

The magneto is set so that with the spark lever fully advanced, the spark occurs while the piston is still $\frac{7}{16}$ inch from upper dead center on Model 48 and $\frac{5}{16}$ inch on Model 38.

McFarlan

1912 Sixes. F.O. 1- 4- 2- 6- 3- 5.

Eisemann magneto; interrupter set back of center at full retard, $\frac{1}{2}$ inch.

1913 Sixes. Teetor motor. F.O. 1- 5- 3- 6- 2- 4.

Interrupter set back of center at full retard, $\frac{1}{2}$ inch.

Herschel motor. F.O. 1- 4- 2- 6- 3- 5.

Eisemann magneto; interrupter set back of center at full retard, $\frac{1}{2}$ inch.

1914 Sixes. F.O. 1- 5- 3- 6- 2- 4.

Mea magneto; interrupter set back of center at full retard, $\frac{1}{2}$ inch.

1915–17 Sixes. F.O. 1- 5- 3- 6- 4- 2.

Westinghouse and Bosch; interrupter set back of center at full retard, $\frac{3}{4}$ inch. The amount of advance provided is 25° on the interrupter housing, with the exception of Model 65, which has $15\frac{1}{2}$° automatic advance and $17\frac{1}{2}$° hand advance.

Madison

Sixes. F.O. 1- 5- 3- 6- 2- 4.

Eights. F.O. 1R- 1L- 3R- 3L- 4R- 4L- 2R- 2L.

Battery ignition.

Marion-Handley

1916–17 Sixes. F.O. 1- 5- 3- 6- 4- 2.

Marmon

Up to 1912 Fours. F.O. 1- 3- 4- 2.

1913–17 Sixes. F.O. 1- 5- 3- 6- 2- 4.

Magneto setting point, with spark lever fully retarded, one inch past upper dead center, as measured on flywheel; maximum advance 35°.

Maxwell

Model 25. F.O. 3- 4- 2- 1.

Magneto is set to fire, with spark lever at fully retard when piston has traveled $\frac{1}{32}$ inch down on firing stroke.

Mercer

1913–17 Fours. F.O. 1- 3- 4- 2.

Magneto setting, with spark lever fully advanced, 1 inch before piston reaches upper dead center, or 41° on flywheel.

Militaire

Fours. F.O. 1- 3- 4- 2.

Setting point; extreme retard, upper dead center.

Mitchell

Fours. F.O. 1- 3- 4- 2.

Sixes. F.O. 1- 5- 3- 6- 2- 4.

1912–14 Models, inclusive.

Magneto setting; extreme retard, upper dead center.

1915–16 Models, inclusive.

Battery ignition; setting point, 10° past upper dead center; maximum advance 40°.

Moline

All Models. Fours. F.O. 1- 3- 4- 2.

Magneto, set to fire at upper dead center with spark lever fully retarded.

Monroe

Fours. Model 2. F.O. 1- 2- 4- 3.

Models, 3–4. F.O. 1- 3- 4- 2.

Battery ignition.

Moon

1916–17 Sixes. F.O. 1- 5- 3- 6- 2- 4.

Murray

Eights. F.O. 1R- 1L- 3R- 3L- 4R- 4L- 2R- 2L.

Magneto setting; extreme retard, 1 inch past center line on flywheel.

National

1913–16 Sixes. F.O. 1- 5- 3- 6- 2- 4.

1916–17 Twelves. F.O. 1- 12- 9- 4- 5- 8- 11- 2- 3- 10- 7- 6.

Magneto setting point, with spark lever fully advanced, $1\frac{1}{4}$ inches on flywheel before piston reaches upper dead center.

Oakland

All Four-Cylinder Models. F.O. 1- 3- 4- 2.

All Sixes. F.O. 1- 5- 3- 6- 2- 4.

Eights. F.O. 1- 8- 3- 6- 4- 5- 2- 7.

Maximum advance allowed, 24°.

Oldsmobile

Models 42–43. Fours. F.O. 1- 3- 4- 2.

Delco battery ignition system; maximum advance 80°; maximum retard 40°, measured on flywheel, on all models.

Model 54. Sixes. F.O. 1- 5- 3- 6- 2- 4.

Model 44. Eights. F.O. 1- 8- 3- 6- 4- 5- 2- 7.

Packard

Up to 1912. Fours. F.O. 1- 2- 4- 3.

Magneto setting point, with spark lever fully advanced, $\frac{15}{16}$ inch before piston reaches upper dead center.

1912–15 Sixes. F.O. 1- 4- 2- 6- 3- 5.

Magneto setting point, with spark lever fully advanced, $\frac{7}{16}$ to $\frac{1}{2}$ inch before piston reaches upper dead center.

1916–17 Twelves. F.O. 1R- 6L- 4R- 3L- 2R- 5L- 6R- 1L- 3R- 4L- 5R- 2L.

It will be noted that this firing order is the same in each block of six cylinders, beginning with No. 1 in the right block and following with No. 6 in the left, as in the six-cylinder model.

Maximum advance, $\frac{7}{8}$ inch before piston at upper dead center.

The variation in the amount of advance allowed is accounted for by the difference in speed. The four-cylinder motors were equipped with a low-tension magneto having a considerable ignition lag, so that a large amount of advance was necessary. The six-cylinder motors ran at a higher speed and were equipped with a high-tension magneto in which the ignition lag was greatly reduced, so that not as much advance was necessary. While the ignition system of the twin-six motor has no greater lag than the high-tension magneto used on the six-cylinder motor, the speed is so much greater that an amount of advance approximately equal to that of the much slower four-cylinder motor is necessary.

Paige-Detroit

1911–14 Fours. F.O. 1- 3- 4- 2.

1915–17 Sixes. F.O. 1- 5- 3- 6- 2- 4.

Pathfinder

Twelves. F.O. 1R- 1L- 4R- 4L- 2R- 2L- 6R- 6L- 3R- 3L- 5R- 5L. Battery ignition.

Patterson

1911–12–13 Fours. Models 30, 41, 43, 45, and 47. F.O. 1- 3- 4- 2.

1914–15. Model Four-32. F.O. 1- 3- 4- 2.

1915 Sixes. Model Six-48. F.O. 1- 5- 3- 6- 2- 4.

1916. Model Six-42. F.O. 1- 5- 3- 6- 2- 4.

1917. Model Six-45. F.O. 1- 5- 3- 6- 2- 4.

Magneto settings; extreme retard, dead center, on all models.

Peerless

1912 Fours. F.O. 1- 2- 4- 3.

Sixes. Models J and K. F.O. 1- 3- 2- 6- 4- 5.

Sixes. Model L. F.O. 1- 4- 2- 6- 3- 5.

1913–14 Sixes. F.O. 1- 4- 2- 6- 3- 5.

1915 Sixes. Model 5K. F.O. 1- 4- 2- 6- 3- 5.

Sixes. Model EE. F.O. 1- 5- 3- 6- 2- 4.

Fours. Model DD. F.O. 1- 3- 4- 2.

1916 Eights. F.O. 1R- 1L- 3R- 3L- 4R- 4L- 2R- 2L.

1917 Eights. F.O. 1R- 4L- 3R- 2L- 4R- 1L- 2R- 3L.

Model 2J. Full advance is equivalent to $3\frac{1}{2}$ inches before dead center, as measured on the flywheel.

Model 2K, $3\frac{5}{8}$ inches before dead center.

Model 2L, $2\frac{7}{8}$ inches before dead center.

Model 5K, 4 inches before dead center.

Model TC (commercial motor), 28°, or 4.68 inches, before dead center on maximum advance and 7°, or 1.17 inches, past dead center on full retard.

Last 50 Model 2K, $2\frac{3}{4}$ inches full advance instead of $3\frac{5}{8}$ inches.

Pierce=Arrow

All Sixes. F.O. 1- 5- 3- 6- 2- 4.

Model C4. Magneto set to have interrupter contacts open when magneto mark on flywheel is directly opposite pointer on crankcase; battery system; spark occurs when igniter mark on flywheel is opposite pointer on crankcase and mark indicating cranks of Nos. 1 and 6 cylinders is directly on top center.

Model B4. Magneto set to have interrupter contacts open when magneto mark on flywheel registers with pointer and mark indicating cranks of Nos. 1 and 6 cylinders is $\frac{3}{16}$ inch over top center; battery system; spark occurs when igniter mark on flywheel registers with pointer and mark indicating cranks Nos. 1 and 6 cylinders is directly on top center.

Model A4. Magneto set to have interrupter contacts open when magneto mark on flywheel registers with pointer and mark indicating cranks Nos. 1 and 6 cylinders is $1\frac{3}{4}$ inches over top center; battery system; spark occurs when igniter mark on flywheel registers with pointer and mark indicating cranks Nos. 1 and 6 cylinders is $\frac{1}{4}$ inch over top center.

Pilliod

Fours. F.O. 1- 3- 4- 2.

Magneto set to give 15° retard and 15° advance.

Premier

1916–17 Sixes. F.O. 1- 5- 3- 6- 2- 4.

With the spark lever fully retarded, the breaker points are set to open 2° to 3° late on flywheel, while the maximum advance is 25°. The pistons are not accessible when motor is fully assembled.

Princess

Fours. F.O. 1- 2- 4- 3.

Setting point for magneto, 8° past dead center at full retard; maximum advance 20°.

Pullman

Fours. F.O. 1- 2- 4- 3.

Regal

All Fours except 1915–16. F.O. 1- 2- 4- 3.

1915–16 Fours. F.O. 1- 3- 4- 2.

1916–17 Eights. F.O. 1R- 1L- 3R- 3L- 4R- 4L- 2R- 2L.

The magneto in earlier models and battery-ignition system in later cars set to fire at upper dead center, with spark lever in fully retarded position. Remy magneto on 1909–10 cars; Michigan magneto 1910–14; Atwater Kent system 1915 models; Connecticut system 1916 models; and Heinze-Springfield starting, lighting, and ignition system 1917 models. Maximum advance in all cases approximately 30°.

Reo

1910–17 Fours. F.O. 1- 3- 4- 2.

1915–17 Sixes. F.O. 1- 4- 2- 6- 3- 5.

1910–15, Four-Cylinder Models. Magneto setting, ½ inch before upper dead center, with spark lever in fully retarded position; maximum advance 5½ inches.

1916–17, Four-Cylinder Models. Magneto setting, upper dead center; maximum advance 6¼ inches.

1915, Six-Cylinder Model. Magneto setting, 1 inch before upper dead center; maximum advance 7½ inches.

1916–17, Six-Cylinder Models. Magneto setting, upper dead center; maximum advance 8½ inches. All measurements are on the periphery of the flywheel; 1 inch on the latter is equivalent to 7.10°.

Ross

Eights. F.O. 1R- 2L- 5R- 6L- 7R- 8L- 3R- 4L.

Battery ignition.

Saxon

Fours. F.O. 1- 3- 4- 2.

Sixes. F.O. 1- 5- 3- 6- 2- 4.

Scripps-Booth

Fours. F.O. 1- 3- 4- 2.

Eights. F.O. 1R- 1L- 3R- 3L- 4R- 4L- 2R- 2L.

Simplex

Fours. F.O. 1- 3- 4- 2.

Sixes. F.O. 1- 4- 2- 6- 3- 5.

Singer

Sixes. F.O. 1- 4- 2- 6- 3- 5.

Magneto setting; extreme retard, top dead center.

Spaulding

Fours. F.O. 1- 3- 4- 2.

Models CP and CS, Remy magneto; Model E, Bosch magneto; Model G, Eisemann magneto; Models H and I, Simms magneto; magneto settings; extreme retard, dead center.

Sphinx

Fours. F.O. 1- 3- 4- 2.

Battery ignition.

Standard

Eights. F.O. 1R- 1L- 3R- 3L- 4R- 4L- 2R- 2L.

Ignition setting point, magneto contacts just opening with piston 2 inches (on flywheel) past dead center, at full retard; maximum advance 25°.

Stearns

1912–14 Fours. F.O. 1- 2- 4- 3.

1915–17 Fours. F.O. 1- 3- 4- 2.

1913–15 Sixes. F.O. 1- 5- 3- 6- 2- 4.

1916–17 Eights. F.O. 1R- 8L- 3R- 6L- 4R- 5L- 2R- 7L.

All the above have the Knight motor.

1915–17. Magneto setting, with the spark lever fully retarded, is 1½ inches past dead center, as measured on the flywheel.

On all other models, the magneto setting point is upper dead center; maximum advance in all cases is approximately 30°.

Studebaker

Model 20. Fours. F.O. 1- 2- 4- 3.

All Other Fours. F.O. 1- 3- 4- 2.

All Sixes. F.O. 1- 5- 3- 6- 2- 4.

All Four-Cylinder Models. Ignition setting point is 4 inches before upper dead center, as measured on the flywheel. All Six-Cylinder Models. Ignition setting point is 5⅛ inches before upper dead center, as measured on the flywheel.

Stutz

All Four-Cylinder Models. F.O. 1- 3- 4- 2.

All Six-Cylinder Models. F.O. 1- 4- 2- 6- 3- 5.

Sun

Sixes. F.O. 1- 4- 2- 6- 3- 5.

Thomas

Sixes. F.O. 1- 4- 2- 6- 3- 5.

Ignition setting point, magneto contacts opening ½ inch on travel of piston before upper dead center at full advance.

Trumbull

Fours. F.O. 1- 3- 4- 2.

Fixed ignition setting.

Velie

1916–17 Sixes. F.O. 1- 5- 3- 6- 2- 4.

Ignition setting point, upper dead center with spark lever fully retarded.

Westcott

1910–14 Fours. F.O. 1- 3- 4- 2.

1913–17 Sixes. F.O. 1- 5- 3- 6- 2- 4.

1910–14. Remy and Bosch magnetos; ignition setting point, upper dead center.

1914 Fours. Atwater Kent system, upper dead center.

1913 Sixes. Bosch magneto; ignition setting point, with spark lever fully retarded, $1\frac{1}{8}$ inches late, or past dead center.

1915 and later Sixes. Delco ignition.

Willys-Overland

All Four-Cylinder Models. F.O. 1- 3- 4- 2.

All Six-Cylinder Models. F.O. 1- 5- 3- 6- 2- 4.

Magneto setting point, with spark lever fully retarded, $\frac{3}{4}$ inch to $1\frac{1}{4}$ inches late, or past dead center; maximum advance 30° to 35°.

Winton

Since 1907. Sixes. F.O. 1- 5- 3- 6- 2- 4.

Magneto setting point with spark lever fully retarded, upper dead center.

Wiring. *Necessity for High-Tension Cables.* Mention has been made of the fact that in early days much trouble was experienced with poorly insulated and poorly mounted wires. This was particularly the case with the secondary circuits, the insulation of which was frequently inadequate to carry currents at the high potentials employed, so that there was more or less leakage. This was further aggravated by the chafing, or rubbing, of these wires against moving parts. The former trouble was eliminated by the adoption of specially constructed cables which are tested to carry 30,000 volts. Cables of this type are illustrated in Fig. 111, which also shows the cables employed for electric lighting and starting installations, where the chief difficulty has usually been the selection of a cable of too small a carrying capacity for the current used.

The importance of using heavily insulated cables for both the primary and secondary cables of the ignition, and, more particularly

the latter, has come to be generally understood, and cables especially designed for this service have now been in use for a number of years; but the importance of using wiring of ample capacity, in the lighting and starting circuits, is not so well appreciated. In the former instance, the problem was one of insulation only, the amount necessary to prevent leakage of the secondary current not being fully realized in the early days; nor was the necessity for thoroughly protecting the primary cables from the effects of oil and water taken into account. Trouble from these sources, however, have long since been a matter of the past; even the well-insulated cables now in general

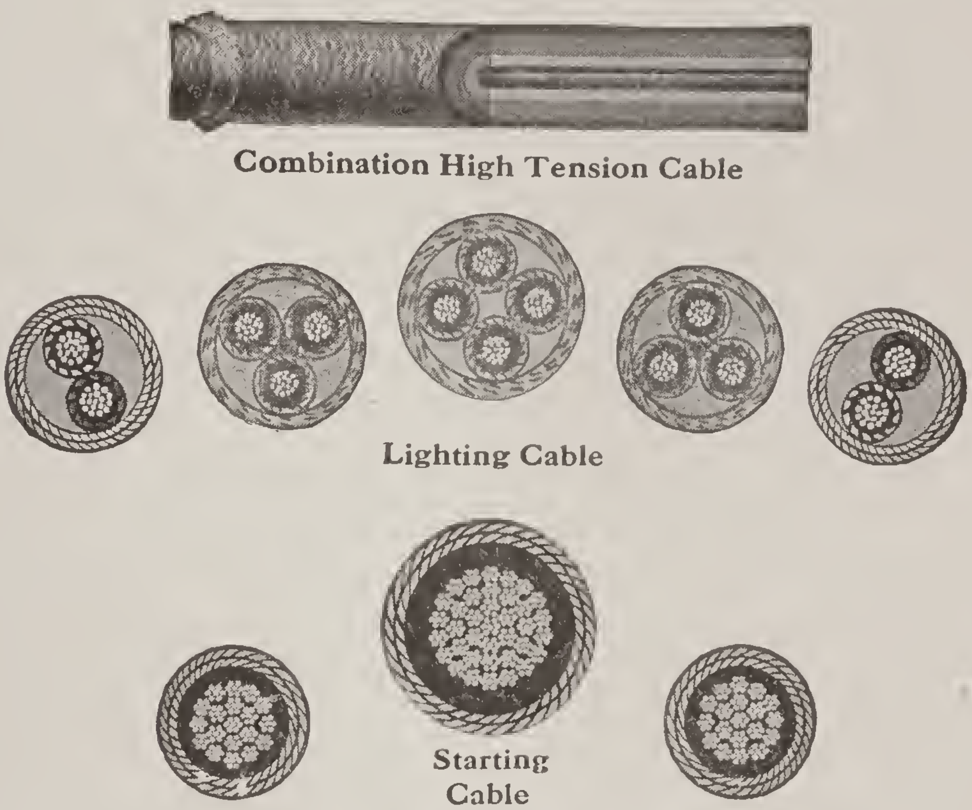


Fig. 111. Types of Cables Employed in Electrical Equipment of Automobiles

use become oil soaked in time, but, when faulty ignition is thought to be due to them, they are promptly replaced.

In many of the early electric starting and lighting systems, the wiring has been as poorly adapted to the purpose as was that of the pioneer ignition systems. This was not on account of improper insulation but owing rather to poor design or to a lack of consideration of the importance that proper wiring has on the efficient operation of the system. No electrical system of this kind is any better than its storage battery; and, as the amount of energy that can be husbanded in the latter is limited, every effort must be made to avoid waste in its use. What constitutes waste in a standard lighting system using current at 110 to 115 volts, and what may be so termed

where the available potential is only 6 volts, are two very different things. A voltage drop of one to 5 volts in an incandescent lighting system is negligible. A drop of 5 volts below the 110-volt standard will cause a perceptible dimming of the lamps, but the life of the lamp filaments themselves will be greatly increased, other factors remaining the same, so that the loss in efficiency is not of such great moment.

Importance of Voltage Drop. But, in an electric starting and lighting system, the loss of even a fraction of a volt due to the wiring represents a substantial falling off in the power. As mentioned in the introductory, the unit of potential, or voltage, times the unit of current flow, or ampere, equals the watt or power unit, and there are 746 watts in an electrical horsepower. Take the case of an electric-starting motor with an unusually long connection between the battery and the electric motor. Assuming that the length and diameter of this wire is such that there is a loss of *1 volt* between the battery and the motor and that, at the moment of starting, 300 amperes are required to *break away* the engine, i.e., free the pistons and bearings when the lubricating oil has thickened from the cold so as to bind them. In the actual power consumed, this voltage drop represents 300×1, or 300 watts, equivalent to more than $\frac{3}{7}$ horsepower.

The loss of but $\frac{1}{2}$ volt, other factors remaining the same, is equivalent to almost $\frac{1}{6}$ horsepower, or about what a strong man can exert for a limited time. This appears to be getting things down pretty fine, but in the case of the Dyneto system, the manufacturers specify that the cable between the starting motor and the storage battery must be large enough to transmit *400 amperes with a total loss not to exceed $\frac{1}{4}$ volt.* With this amount of current, the voltage drop in question represents 100 watts, or nearly $\frac{1}{7}$ horsepower. Of course, this loss only takes place at the instant of starting, but that is just the time when the highest efficiency and the full power of the battery is required. Moreover, the starting motor frequently has to be operated a number of times, especially in cold weather when the battery efficiency is at its lowest, before the engine will start. Even at the lower-current values necessary for turning the engine over after it has been broken away, a drop of one volt represents an appreciable power loss, as the current consumed is anywhere from 50 to 100 amperes. It will be apparent from this why the manufacturers lay such emphasis on their instructions not to lengthen connections, if avoidable,

and then only to use wire of the same size and kind. This, of course, does not apply to the starting motor connection, as that should never be lengthened without increasing the diameter of the wire to compensate for the increase in length.

Calculating Size of Cable. It is not advisable to do so where it can possibly be avoided, but, when made necessary by the fitting of an enclosed body, the following formula should be used for calculating the size of cable that should be employed:

$$\frac{\text{Maximum current} \times 10.7 \times \text{number of feet of wire}}{.25} = \text{diameter or cross-}$$

section of wire in circular mils

For example, in the case cited above, where the maximum current at the instant of starting is 300 amperes and the distance between the battery and the starting motor is four feet (measured from battery to switch and from the latter to the starting-motor terminal), the size of wire necessary would be:

$$\frac{300 \times 10.7 \times 4}{.25} = 48{,}960 \text{ circular mils}$$

As shown in the table on page 27, which gives the corresponding sizes of the B & S gage, the nearest to this is No. 3 wire of 52,634 circular mils cross-section, but, to allow for a factor of safety, either a No. 2 or a No. 1 wire would be used for such an installation. Now, in case it becomes necessary to take the battery from the running board close to the engine and place it under the floor of an enclosed body, increasing the length of wire needed to 8 feet, the cross-section of the wire required would be 98,720 circular mils, the closest gage number to this being the No. 0 cable. In other words, doubling the length of the cable would make it necessary to double its cross-section in order to prevent exceeding the minimum permissible drop in the voltage. This will make plain why some of the amateur experiments in re-locating the essentials of an electric starting system have had such disastrous effects on its efficiency.

Effect on Lights. In the case of the lamps, the effect of an increased drop in the voltage is not so serious; though, because of the very low-battery voltage available, what would otherwise be a

negligible loss assumes important proportions. On the 3-cell 6-volt battery now so generally used, the lamp filaments are designed to burn to full brightness on a potential of 6 to 8 volts, this variation being provided to compensate for the difference in the battery voltage when fully charged and when partly discharged, as the voltage of the battery decreases as it discharges, dropping to but 1.50 volts per cell when practically exhausted, or a total of $4\frac{1}{2}$ volts. Even if receiving this full voltage, the 6-volt bulbs would burn very dimly, but there must be deducted from it the voltage drop due to the wiring and the switches. This is the reason why the brightness of the lamps (with the generator idle) affords such an excellent indication of the state of charge of the battery.

It will be apparent from the above that a drop in potential of but one volt in the lighting circuit would cause a serious loss of efficiency at the bulbs. Assuming that the headlights consume 4 to 5 amperes, and applying the above formula on the basis of a maximum distance of 10 feet from the battery, it is found that a No. 16 wire is necessary; but, in order to provide a large factor of safety, nothing smaller than No. 14 wire is ordinarily employed for the lighting circuits, and, in some cases, it is No. 12.

Importance of Good Connections. Under the head of "Resistance", however, attention has been called to the fact that not alone the length and size of the connecting wires, but also all switches and joints are factors in calculating the total resistance of a circuit. Consequently, it is poor practice ever to make a joint in a wire where a single length may be employed. Whenever a wire is broken by accident, the trouble should always be remedied by replacing it with an entirely new piece rather than by making a joint in the old wire. Loose connections also add greatly to the total resistance in a circuit, as well as connections in which the contact faces of the terminals are dirty or corroded. In replacing or tightening connections, care should be taken to see that the parts in contact are scraped or filed bright and that both the terminal nut and its lock nut are screwed down firmly. The switches are also an important factor where voltage drop is concerned and switch blades or contacts that are dirty or corroded, or that are not held firmly in contact when closed, will be responsible for an appreciable drop in the voltage that will become increasingly perceptible as the battery becomes discharged.

Magneto Mounting. As the magneto is timed exactly with the motor, it must be positively driven synchronously with it at a speed depending upon the number of cylinders. This is crankshaft speed on a four-cylinder and one and one-half times crankshaft speed on a six. It has become standard practice to a very large extent both here and abroad to mount the magneto on a "pad" or shelf attached to the crankcase and drive it from a special auxiliary shaft, usually also utilized for driving the water pump or other motor auxiliary. Variations from this are to be found in the Renault and a few other European as well as American cars, in which the magneto is mounted

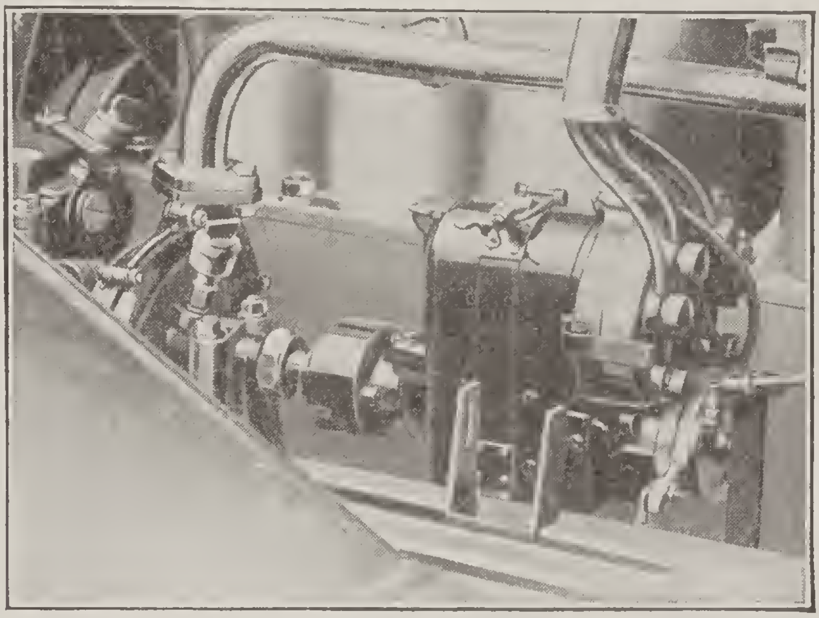
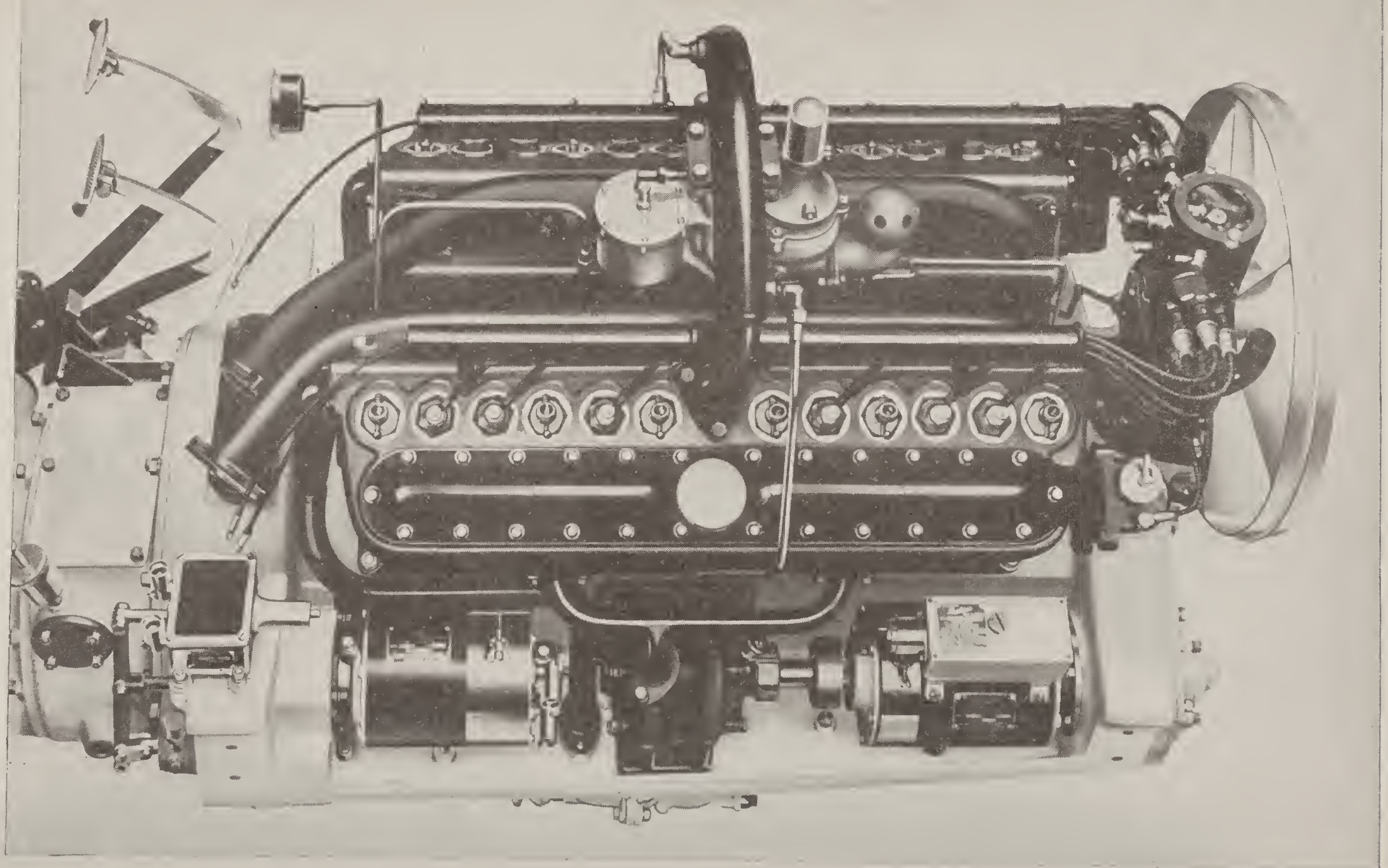


Fig. 112. Mounting of Magneto on Lozier Car

at the forward end of the motor and driven by a cross-shaft and helical gears directly from the crankshaft of the motor. The only advantage of this is slightly greater accessibility. In any case, the magneto is not permanently fastened but is simply held on its support, against movement, by dowel pins in the base and a strap clamp tightened with a thumb nut, as shown in Fig. 112, which may be regarded as typical of American practice. As the efficiency of the magneto depends to a considerable extent on the very limited clearance between its armature and the pole pieces of the field, usually termed the armature tunnel, precautions are taken to avoid placing any stress on it that could tend to disturb this accurate alignment. The driving shaft is accordingly provided with a universal joint, the long familiar Oldham coupling being much used in this country for the purpose. On the Pierce-Arrow a leather disc universal drives the magneto and also cushions the armature.



BIJUR STARTING MOTOR AND GENERATOR MOUNTED ON PACKARD "TWIN SIX"

The generator is used for ignition purposes, the coils and distributors being seen at the upper left portion of the illustration.

Courtesy of Bijur Motor Lighting Company, Indianapolis, Indiana

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART III

IGNITION—(Continued)

MODERN BATTERY IGNITION SYSTEMS

Effect of Starting and Lighting Developments on Ignition. Prior to the advent of the electrical starting and lighting systems, the magneto had reached a degree of development that appeared to leave not the slightest doubt as to its representing the ultimate type of ignition current generator. With the installation of a direct-current generator capable of supplying more than enough current for lighting and starting the car and charging a storage battery of high capacity, however, it appeared that there was a duplication of electrical apparatus for which there was no good economic reason. In other words, with such an ample and reliable source of current on the car as that presented by the charging generator and storage battery, why continue the magneto? There is no sound reason why one electrical system should not combine all three functions of ignition, lighting, and starting, and this has been successfully carried out on the Cadillac for several years past, while the Reo and other makes have more recently followed suit.

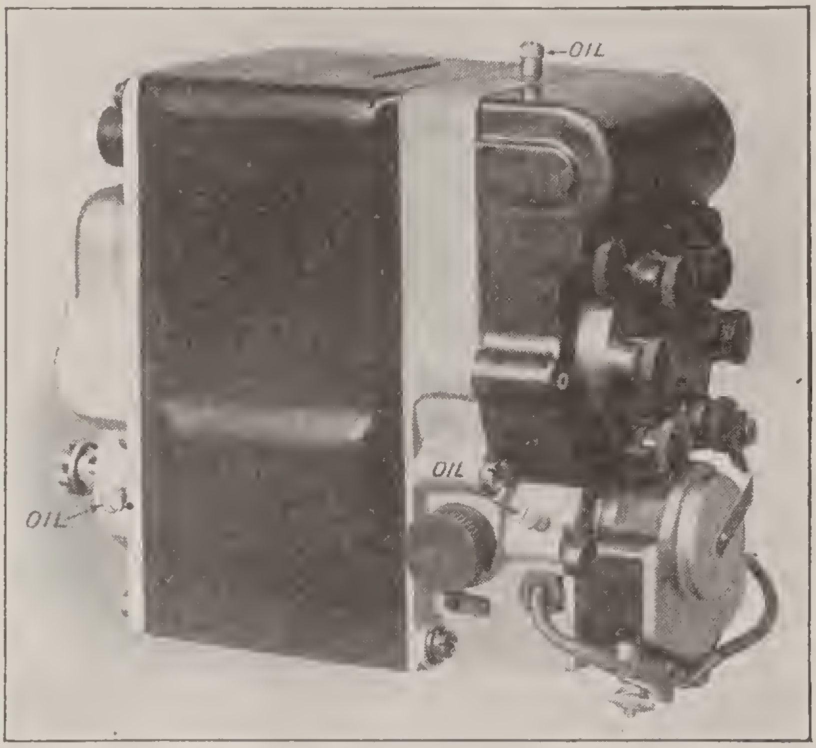


Fig. 113. Westinghouse Generator with Ignition Distributor

Generator Design Follows Magneto Precedent. Several generator designs have been developed which resemble that of a magneto. In the Westinghouse generator, Fig. 113, and the Remy,

Fig. 114, their contact breakers are of the magneto type, as will be plain from the Remy, Fig. 62, and the Westinghouse, Fig. 115, to cite but two examples of a number. In the case of the Westinghouse, the objection previously held against battery ignition—that it

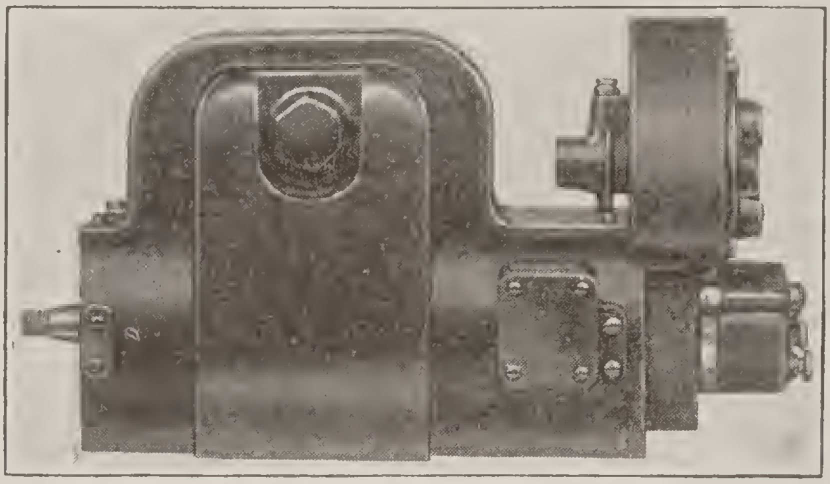


Fig. 114. Remy Combination Lighting and Ignition Generator

required much more manipulation of the spark advance lever to obtain efficient motor running—has been overcome by the provision of a centrifugally operated automatic advance device, Fig. 115, similar in principle and results to the Eisemann and Herz devices, Figs.

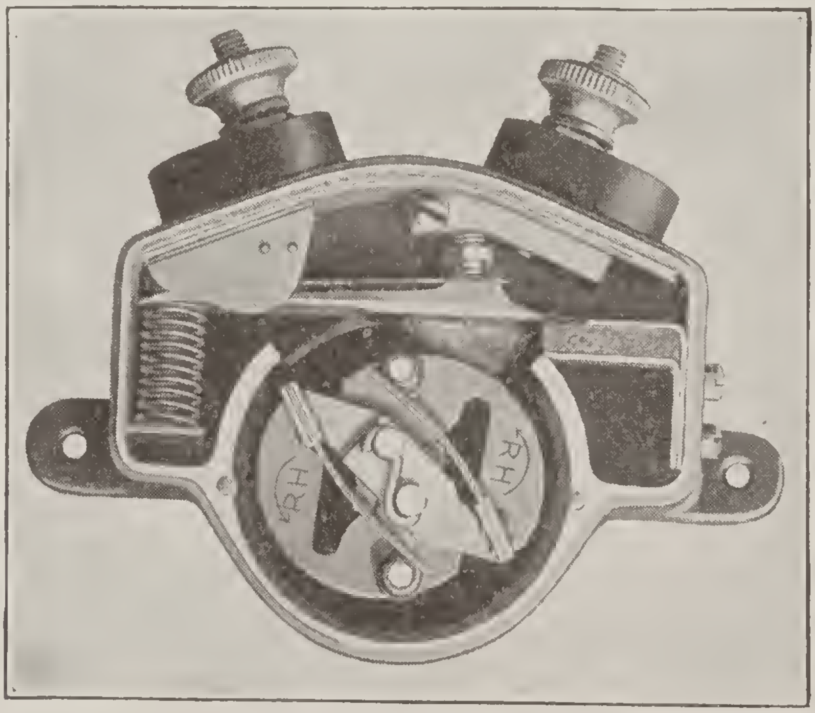


Fig. 115. Westinghouse Contact Breaker with Automatic Spark Advance

102 and 105, though differing from them in construction. The distributors employed are practically identical with those used on magnetos, but all resemblance disappears when the machine is dismantled, Fig. 116, revealing a compact direct-current generator.

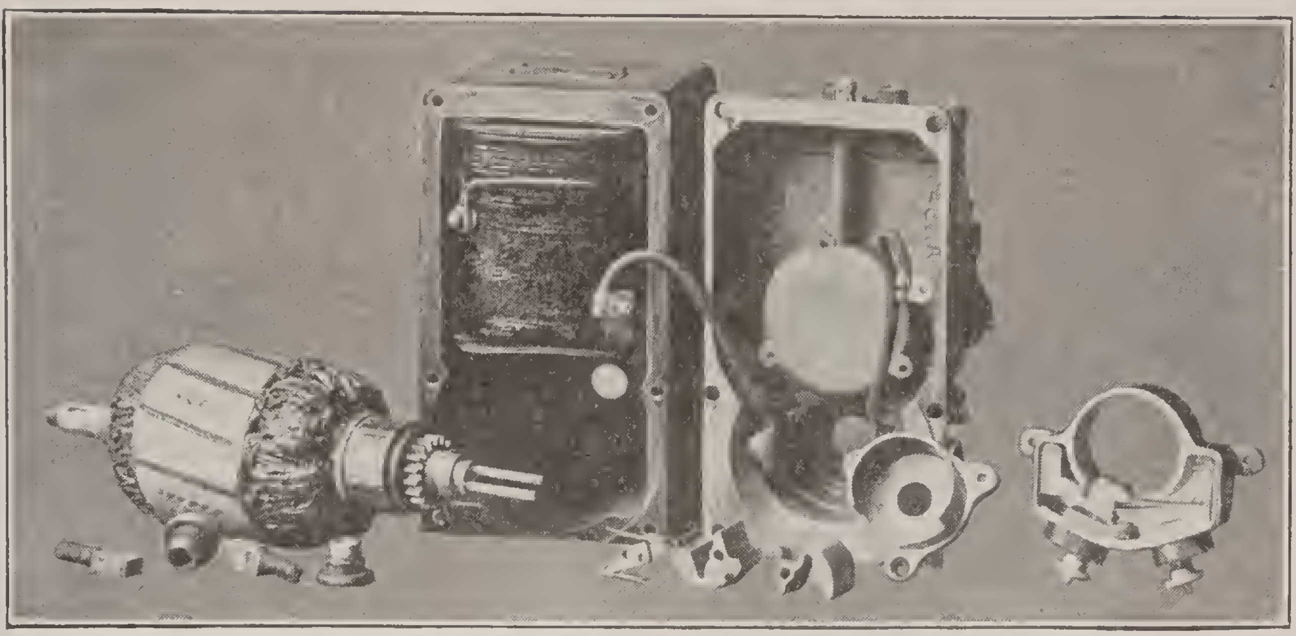


Fig. 116. Details Westinghouse Lighting and Ignition Generator

TYPICAL ARRANGEMENTS

Westinghouse Ignition Unit. This is a combination of all the essentials of magnetic ignition, i.e., the interrupter, distributor, induction coil, and condenser, brought together in a compact unit adapted for mounting either on the lighting generator itself or directly on the engine. It supersedes the type of ignition and lighting generator previously described and which now will be found only on cars of earlier models. As will be noted in Fig. 117, its components are the counterparts of the same essentials on the magneto, except that the interrupter cam has four lobes, so that no further description is necessary.

Fig. 118 is a wiring diagram of the connections. The interrupter and condenser are located at the bottom of the housing with the

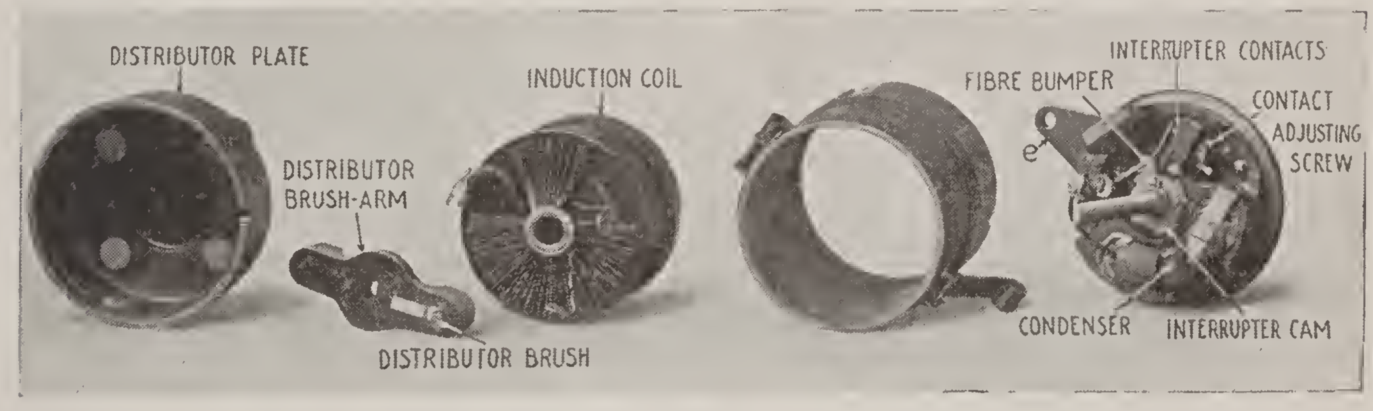


Fig. 117. Details of Westinghouse Ignition Unit
Courtesy of Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania

induction coil above and the distributor at the top. To prevent an excessive amount of current passing through the ignition unit, a

"ballast resistor" is connected in series with it. This is a resistance unit which, in the various models, is combined either with the switch or with the fuse box, or may be mounted independently. In case this resistance unit should become inoperative for any reason, the car may be run by replacing it with a standard 5-ampere fuse cartridge. A fuse of larger capacity than this should not be used and the car should not be run any longer than absolutely necessary with the fuse in place, as the interrupter contacts would be badly burned. The working of the interrupter contacts may be inspected by loosening the set screw at the bottom of the housing and lifting the distributor an inch or so, Fig. 119.

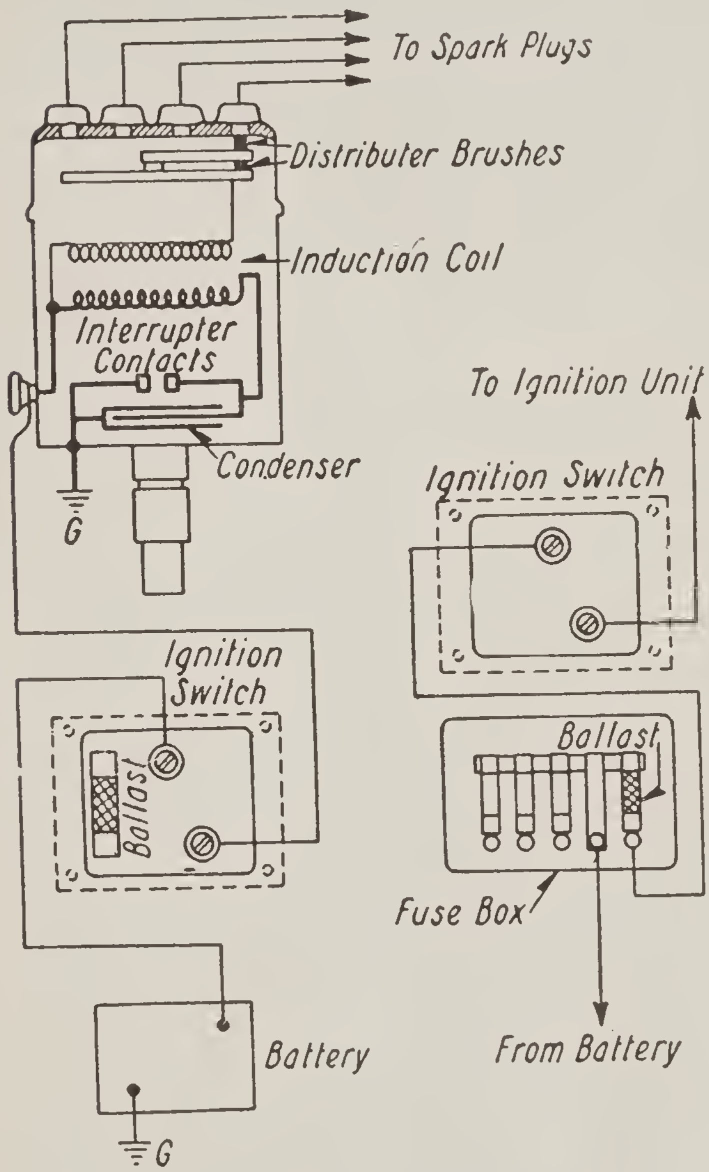


Fig. 118. Wiring Diagram for Vertical Ignition Unit. Left—with Ballast on Rear of Ignition Switch; Right—with Ballast in Fuse Box

Atwater=Kent System. The Atwater-Kent system is based on a "single spark" interrupter and was the pioneer in making battery ignition successful on the modern automobile before the advent of the perfected lighting generator, the current source usually being a dry-cell battery. It was considered an advantage in earlier years to produce a series of high-tension sparks in the cylinder on the theory that, if the first failed to explode the charge, it would be fired by the subsequent sparks. The fallacy of this long since became apparent and the reason therefor has been dwelt upon already. The Atwater-Kent interrupter is typical of devices of this class which have been developed since and as it is fitted on thousands of cars which come to the repair man's attention at one time or another, a detailed description of its working is given here.

Operation of "Unisparker". The ratchet A, Fig. 120, has as many notches as there are cylinders to be fired. It is mounted on the central vertical shaft of the device which also carries a distributor, and in this combined form is known as a "Unisparker". On four-cycle engines it is driven at half crankshaft speed, and at crankshaft speed on two-cycle engines (motor boats). The ratchet A engages the lifter B, and, as A rotates, its teeth or notches successively tend to draw B with them, against the tension of the spring C. In doing

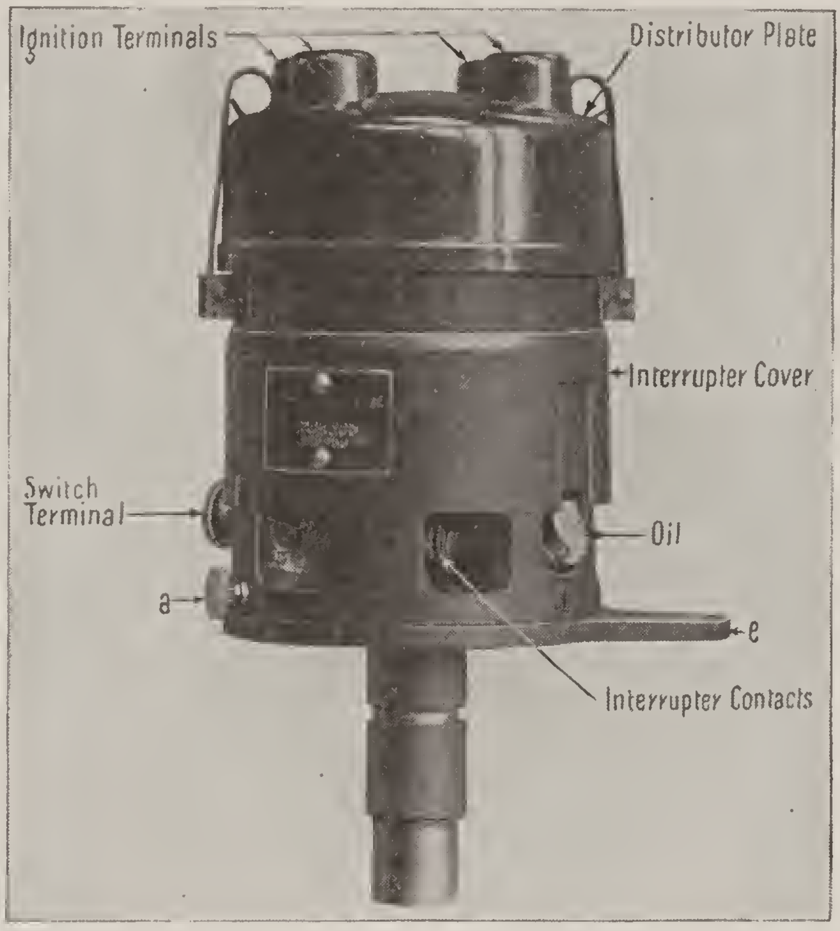


Fig. 119. Westinghouse Ignition Unit with Interrupter Cover Raised Showing Interrupter Contacts
Courtesy of Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania

so, the head of B strikes the swinging lever or "hammer" D, whose motion in both directions is limited as shown, and the hammer communicates the blow to the contact spring E, bringing the contact points together momentarily. E is a compound spring, the straight member of which carries the movable contact, while the stationary contact F is mounted opposite it. The second member of this compound spring is curved at its end to engage the straight member. Ordinarily the straight spring blade is held under the tension of the curved blade and the contact points are held apart.

When the curved blade is struck by the hammer *D* the points contact. The curved blade, however, is thrown over farther by the impact and its hook leaves the straight blade. Upon reaching the

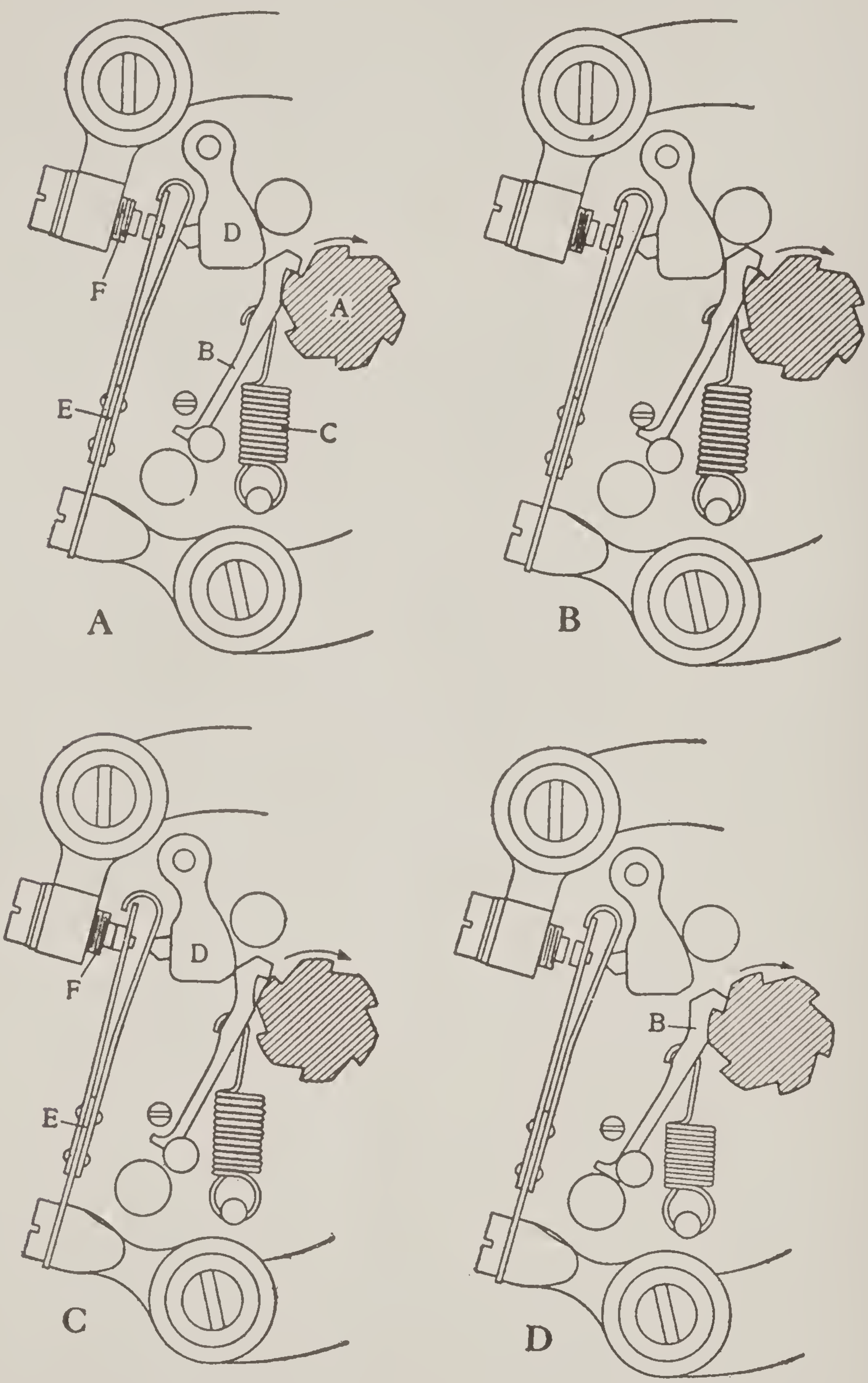


Fig. 120. Diagram Showing Operation of Atwater-Kent Interrupter
Courtesy of "The Horseless Age"

limit of its movement it flies back and strikes the end of the straight blade a blow causing a very sharp break of the circuit. This movement is so extremely rapid that it cannot be detected by the unaided eye, so that its working cannot be tested simply by watching the

operation of the contacts as in the case of a magneto interrupter. *B*, *C*, and *D*, of Fig. 120, show the successive movements of the parts during a single phase. In *A*, a notch of the ratchet has engaged *B* and is drawing it against the tension of the spring *C*. In the second sketch *B*, the hook is released. In *C*, the lifter is riding back over the rounded portion of the ratchet and striking the hammer *D*, which in turn pushes *E* for a brief instant against *F*. The return of *B* to the position shown in sketch *D* is so rapid that the eye cannot follow the movement of the parts *D* and *E*, which to all appearances remain stationary.

Adjustment of the contact points is made by removing one of the thin washers from under the head of the contact screw *F*, and the gap should be .010 to .012 inch, never exceeding the latter. Where more accurate means of determining this distance are not available, it may be gaged with a piece of manila wrapping paper which should be perfectly smooth. With the aid of a "mike" (micrometer) a sheet of paper of the proper thickness can be selected. The contacts are of tungsten and as the moving parts are all of glass-hard steel, very accurately machined, the wear is negligible so that adjustment is not required oftener than once in 10,000 miles running and replacement only after 50,000 miles.

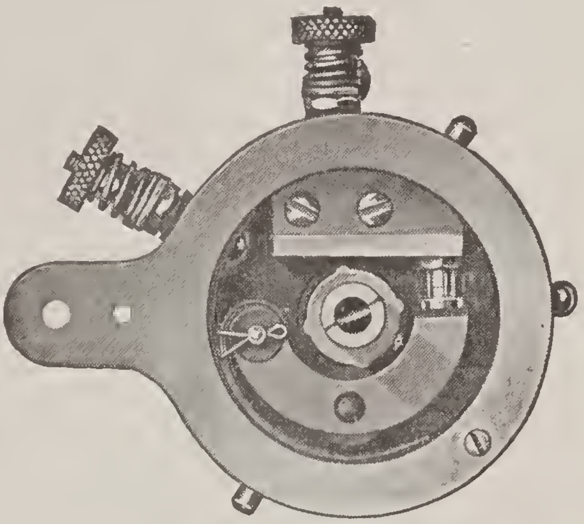


Fig. 121. Connecticut Interrupter

With this interrupter it is impossible to run the battery down by leaving the switch closed inadvertently, as the contacts are never together when the moving parts are idle. The remainder of the system comprises an induction coil (nonvibrator) and a high-tension distributor.

Connecticut Battery System. While this system also employs a single-spark interrupter, it is what is known as a "magneto type", and the similarity to those employed on magnetos for the same purpose will be noted in Fig. 121. A characteristic of this type of interrupter is that its contacts normally remain closed so that if the ignition switch is left on, the battery will be run down. To

prevent this in the Connecticut system, an automatic switch acting on the thermoelectric principle is employed. The interrupter consists of a semicircular arm of sheet steel to make it light. This is pivoted at one end, carries a roller at its center and the movable contact at the other end. It is insulated from its pivot and the roller is of fiber. The vertical binding post is electrically connected with the stationary contact and the second one, at an angle, connects with the movable contact.

Fig. 122. Connecticut Igniter Complete Except for Switch
Courtesy of Connecticut Telephone and Electric Company, Meriden, Connecticut

While an interrupter of this type has practically no lag, means of advancing the moment of ignition are provided (lever extension at left), as the spark must occur earlier at high engine speeds to permit of propagating the flame throughout the charge in the extremely short time available in the modern high-speed engine. As the contacts are opened only momentarily, the interrupter is in circuit most of the time and accordingly is not economical of current, so that it is designed only for use with the battery and generator of the lighting and starting system.

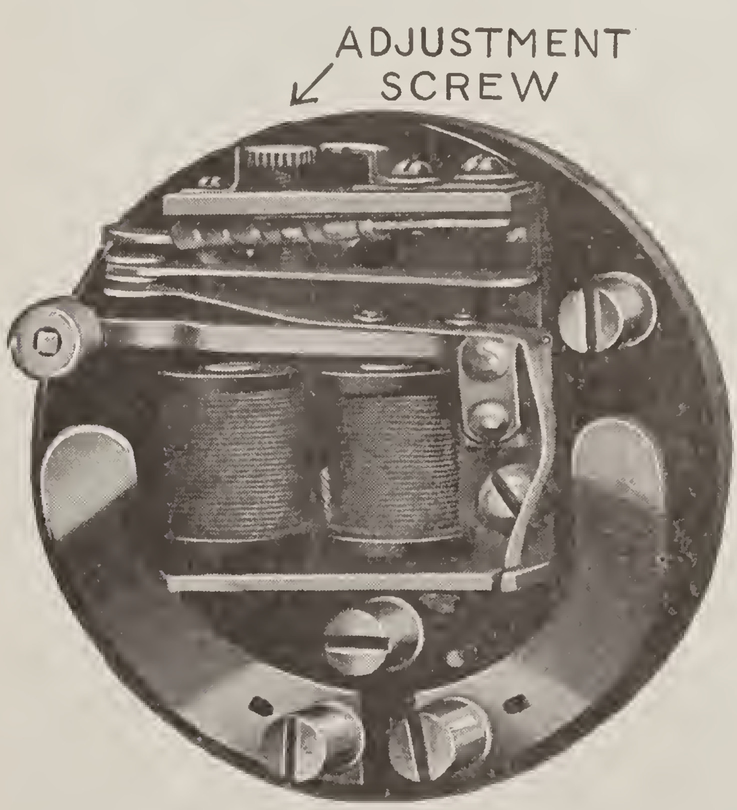


Fig. 123. Connecticut Automatic Switch

Fig. 122, shows the complete Connecticut system (minus the switch) as designed for mounting on a magneto bed plate. The distributor is mounted over the interrupter, while the coil is at the

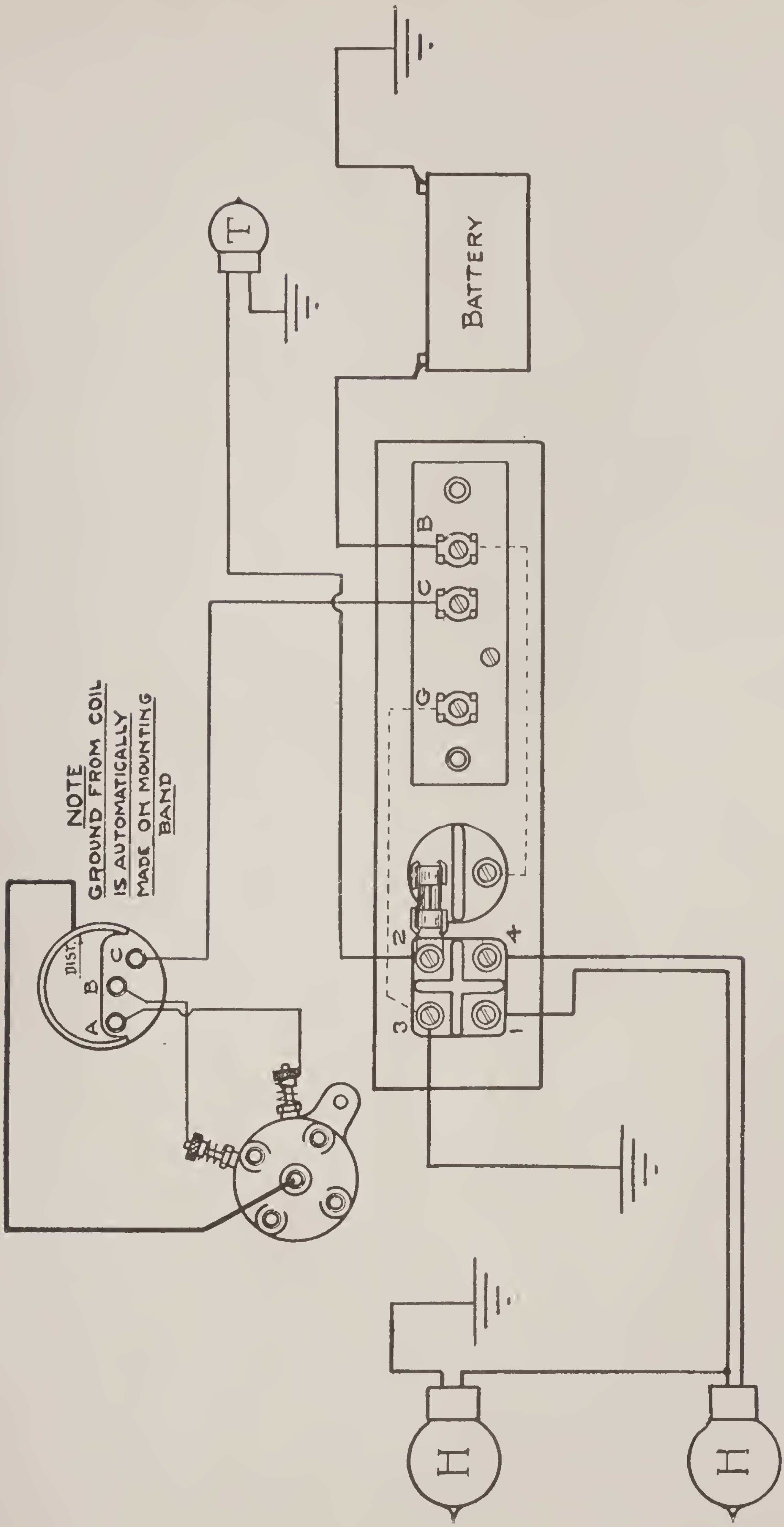


Fig. 124. Wiring Diagram for Connecticut Ignition System

right. The primary of the coil is not grounded, insulated leads being connected to the two binding posts of the interrupter, as shown. The grounding of the secondary winding of the coil is effected through the metal holding band and the bolts fastened to the bed plate. A glass tube is employed to house the safety gap which is mounted under the cover of the coil.

Automatic Switch. The purpose of the automatic switch, Fig. 123, is to open the circuit in case the switch button has been left on with the car stopped. The current passing with the contacts closed, when the engine is idle, is much greater than when it is constantly being interrupted by the rapid-fire action of the cam, but, unlike a circuit-breaker, the device is not designed to act instantly upon the passing of an overload current as this would prevent cranking the motor. The device consists of a thermostatic arm regulated by the adjustment screw at the top of the figure, an electromagnetic vibrator the armature of which carries a hammer, and the necessary connections. Current enters at either the right- or left-hand screw at the bottom, according to whether the switch is closed at the end of the sectors at the right or left of the figure (*M* or *B* on the switch cover plate), and flows through the heater tape on the arm of the thermostat to the screw at the upper right in the figure. This heater tape is a resistance that becomes warm upon the passage of a certain amount of current for a short time and, with an increase in temperature, causes the arm of the thermostat to bend until it makes contact with the upper thermostatic arm. This puts the windings of the magnet in circuit through the post just below the magnet coils and sets the vibrator in motion, causing the hammer on the armature to strike the switch button and open it. Fig. 124 is a typical wiring diagram in connection with the lighting system, the automatic switch being combined with the lighting switch.

Remy System. The relation that the various essentials of a battery-ignition system of the types here described bear to each other is made clear by glancing at the graphic wiring diagram of the Remy system, Fig. 125. The starting switch shown at the left has, of course, no connection with the ignition system but is included in the illustration because the current-supply wire for the latter is connected to one terminal of the starting switch instead of being

taken directly to the battery. This is done simply to save wire. The source of current supply is the storage, and, as is the case with all one-wire systems, one side of the battery is grounded, as shown. Similar ground connections, necessary to complete the circuit, will be noted at the various units of the system. The colors mentioned in connection with the various wires are those of their insulation, which serves to identify them.

Detecting Grounds. All current used by the ignition system passes through the ammeter, which thus serves as a method of detecting grounds. For example, if, with the engine idle and all lamps

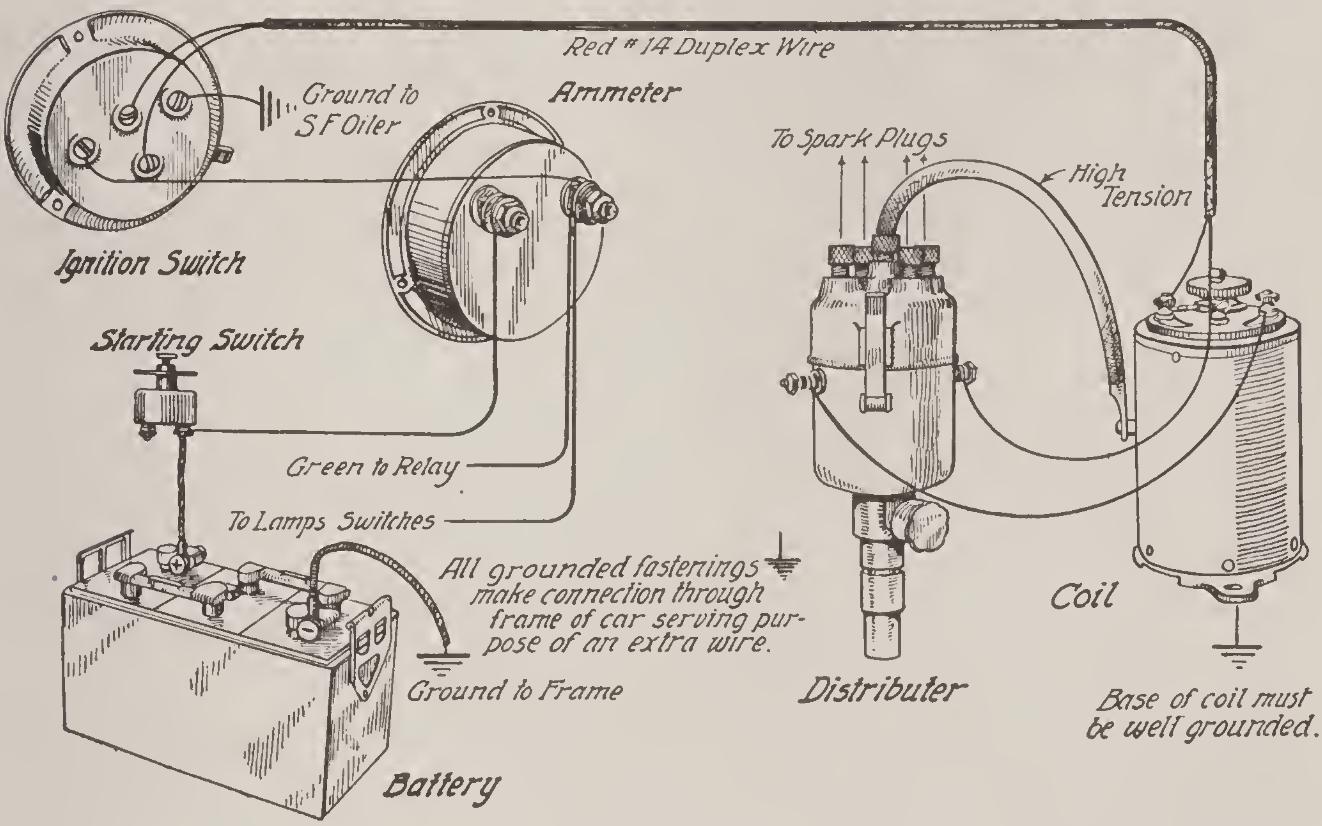


Fig. 125. Essentials of Battery Ignition System

turned off, the ammeter registers a discharge, it indicates a leak in the system. By disconnecting the wires leading to the lamps, relay, and ignition switch in turn, the particular part of the system in which the fault lies may be detected. If, for instance, the ammeter needle immediately drops back to zero upon disconnecting the lead to the ignition switch, it indicates that the leak is in some part of the ignition system; if it still indicates a discharge after disconnecting this lead, it shows that the leak is in one or the other of the two remaining parts of the system to which the wires in question lead, and it may be found by continuing the process of elimination further. Should the ammeter still show a discharge reading after disconnecting

all three of these wires, the trouble would lie either in the starting switch or in the cable connecting it with the battery. This could be proved by disconnecting the switch from the battery and running an independent lead from the battery to the ammeter, temporarily. There is always a possibility, of course, that the fault may lie in the ammeter itself. A current-measuring instrument is necessarily of delicate construction and is apt to suffer from the vibration and jolting. Before carrying out all the above tests, make certain that the ammeter needle has not become stuck.

Ignition Switch. From the ammeter, Fig. 125, the current passes to the ignition switch of the *reversing* type, that is, it serves to change the direction in which the current flows every time it is turned on. For the purposes of either ignition or lighting, it is immaterial in which direction the current flows, but the latter has an important bearing on the life of the expensive contact points in the interrupter. As has been explained previously, the passage of a current through contact points or across a gap tends to transfer the material of the positive electrode to the negative, resulting in the formation of a cone at the positive and a crater, or hollow, at the negative. When the points have worn to this condition through long service, the contact is poor and uncertain, while the points are apt to stick, and to put them in good working order means filing away some of the platinum which is more costly than gold. The use of a reversing switch, which alternately makes the same point positive and negative, keeps both contacts in better condition for a greater length of time.

One side of the ignition switch is grounded on the oiler, through which the current passes to the frame to which the oiler or its support is attached. This particular connection is merely a matter of convenience and is only another instance of saving wire. The wiring diagram in question shows the installation of the Remy system on the Scripps-Booth four-cylinder chassis; on other machines, the ground connection will usually be found in some equally convenient point close to the switch. The two remaining connections from the ignition switch run to the coil and the interrupter, or contact breaker, respectively, and complete the primary circuit.

Interrupter and Distributor. The interrupter is enclosed in the same housing as the distributor, Fig. 125, and is directly below it. As with a magneto, the coil is grounded by attaching it to its pedestal

on the car, the plate shown serving as a ground connection for one side of both the primary and the secondary windings of the coil. Consequently, but one connection for the primary circuit and one for the secondary circuit need be made from the coil to the interrupter.

By tracing the connections just described, it will be plain that when the contacts of the interrupter are closed, current flows from the battery through the primary of the coil. The revolving members of both the interrupter and the distributor are mounted on a vertical shaft driven by helical gearing from one of the half-time shafts of the engine. When the cam on this shaft opens the contact points

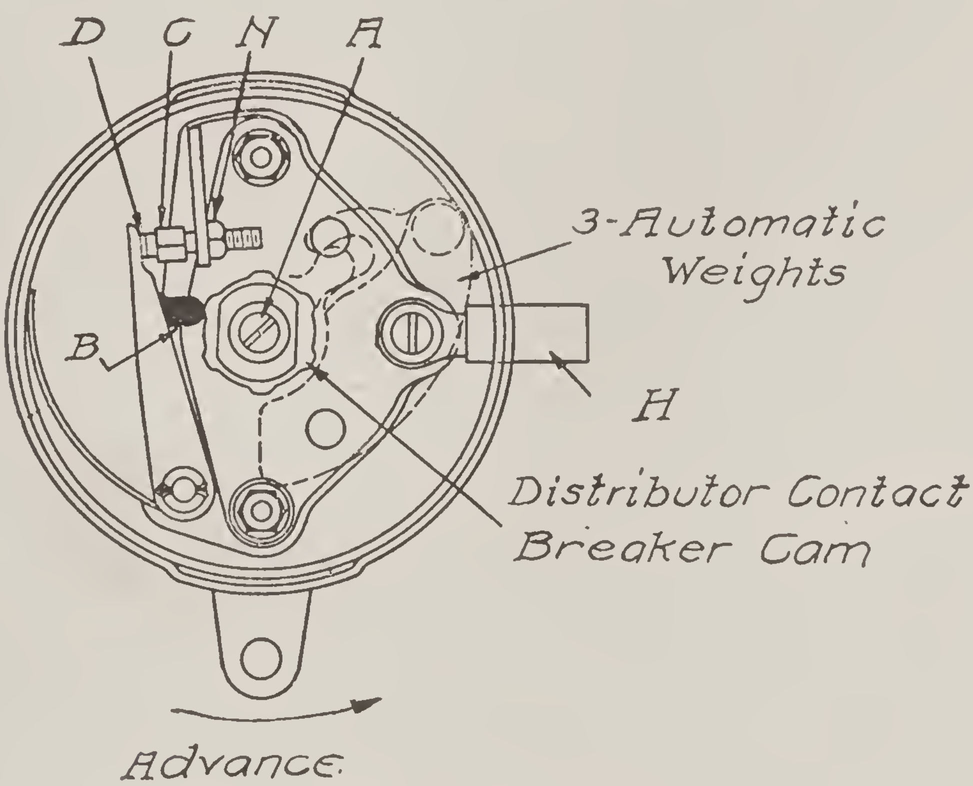


Fig. 126. Delco Magneto Type Interrupter

of the interrupter, the primary circuit is suddenly broken, and a high-tension current is induced in the secondary winding of the coil. As the revolving member of the distributor is timed to make contact with one of its stationary segments every time the contacts of the interrupter open, the secondary current is led to one of the spark plugs. The occurrence of the spark at the plug is practically simultaneous with the opening of the interrupter contacts.

Delco System. A magneto-type interrupter, substantially similar to that of the Connecticut system except that it is provided with an automatic-spark advance, is used, as shown in Fig. 126. The arm *B* carries the movable contact *D* and a fiber-striking lug which bears against the four-part cam and is lifted by its revo-

lution against the tension of the leaf spring held against the inner wall of the housing. The stationary contact is at C and is adjusted by means of the screw and locked in place by the nut N. These contacts should be so adjusted that when the fiber block on B is on top of one of the lobes of the cam, the contacts should open sufficiently to allow the gage on the distributor wrench, provided with the system, to close the gap. As in the Connecticut interrupter, the contacts normally remain closed, being opened momentarily by the cam, which has as many projections as there are cylinders to be fired. This is the later model of Delco interrupter (1916).

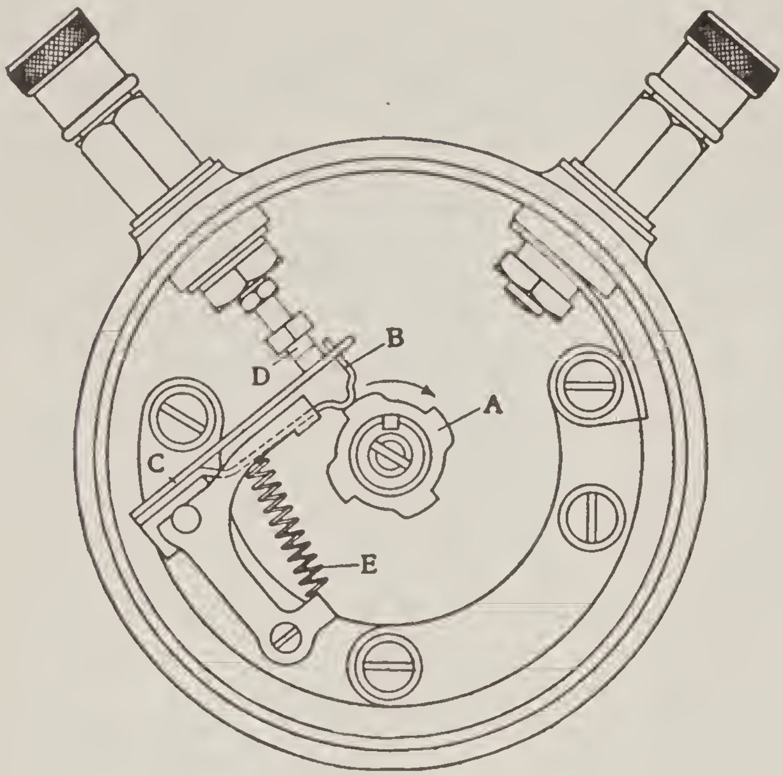


Fig. 127. Diagram of Earlier Model of Delco Interrupter

Earlier Model Interrupter. In an earlier model which will be found on a great many cars, the contacts are normally held open, Fig. 127. The movable contact is carried on a straight spring blade to which is attached a bent spring blade B held against the cam by the spring E. The latter also places the spring C under slight tension and holds the movable contact away from the stationary contact D. When the projection of the cam strikes the raised portion of B, it deflects the latter and allows the contact points to come together. As it passes the bump on B, E

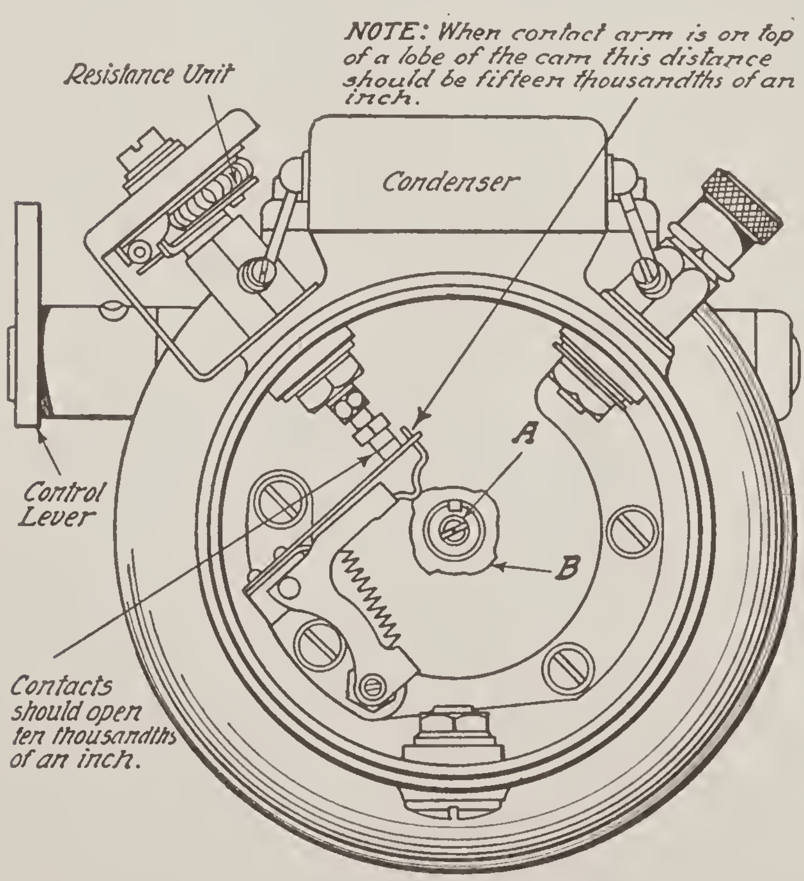


Fig. 128. Delco Timer with Resistance Unit

draws B back sharply, its end strikes C, and the contacts are suddenly opened, the duration of the contact varying with the speed of the engine.

Timer with Resistance Unit. Mention has been made of the fact that the contacts of the interrupter in the battery system of ignition are normally closed, just as they are in the magneto interrupter, only the circuit being opened at this point at the time of ignition. Owing to the rapidity of their action and the extremely short interval

Fig. 129. Four-Cylinder Battery Ignition Unit on Dodge Car (1917)—Coil at Left
Courtesy of Dayton Engineering Laboratories Company, Dayton, Ohio

between contacts in the interrupter of a high-speed engine, this calls for a very small current consumption. Should the ignition switch be left closed when leaving the car, however, the timer cam is just as likely to stop in the closed position as in the open, and this small steady discharge will result in exhausting the storage battery. To prevent this waste of current and possible damage to the contacts and coil, a later type of timer has been provided with a resistance unit. This is shown on the left-hand terminal of the timer, Fig. 128, which illustrates the type used on the Cole, among others. The unit

consists of a small open coil of high-resistance wire wound upon a porcelain spool mounted on the head of the terminal.

All the current passing through the timer must first pass through this resistance winding, but, owing to the extremely short period it continues between interruptions due to the opening of the contact points, the resistance wire remains cool. When the switch has been left on with the engine idle, however, the current is then continuous and of greater value, and it brings the resistance wire to a red heat in a comparatively short time. At this temperature, its resistance increases so greatly that it permits very little current to pass. It will also be noted that the condenser is mounted on the timer in this case.

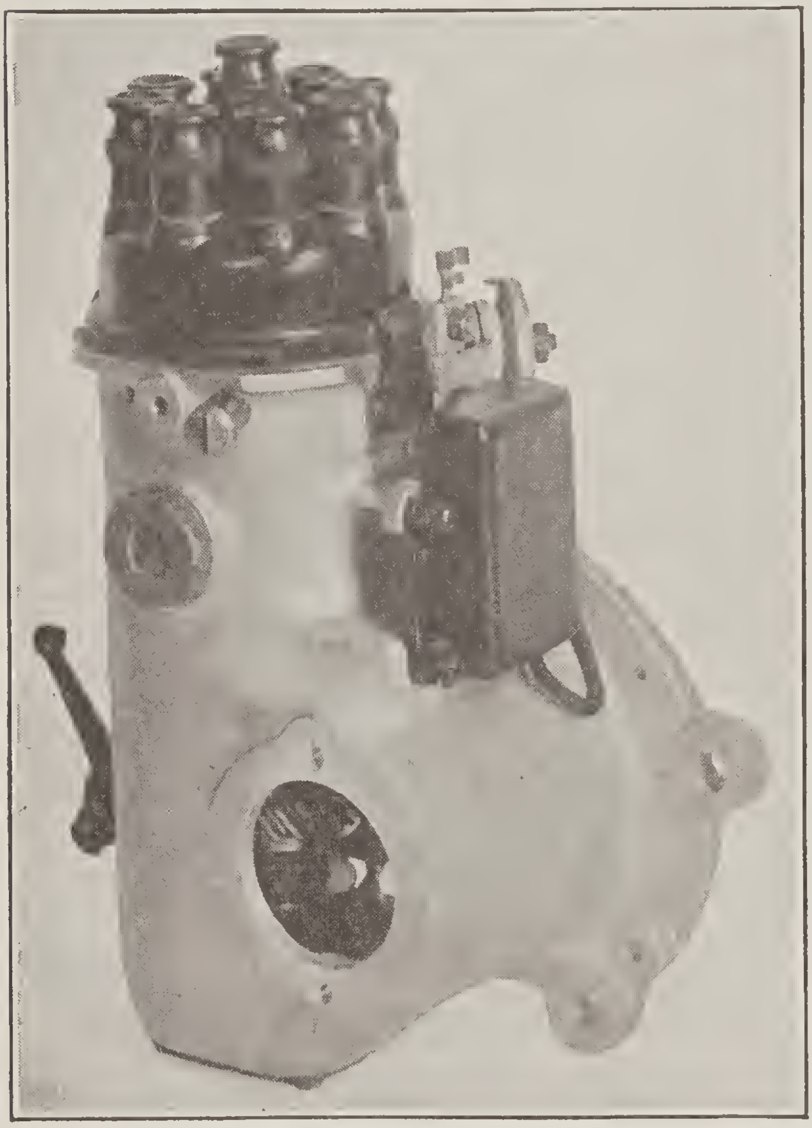


Fig. 130. Eight-Cylinder Distributor and Drive (Delco) as Used on 1917 Cadillac
Courtesy of Dayton Engineering Laboratories Company, Dayton, Ohio

As the spark occurs at the instant the timer contacts are opened, the ignition timing may be altered by moving cam *A* with relation to its shaft, which is done by loosening screw *B*. Turning the cam in a clockwise direction, or to the right, advances the time of ignition, and to the left, or counter-clockwise, retards it. The distributor used in connection with this timer is provided with automatic spark advance, as well as with the usual manual control on the steering wheel. Typical distributors for five-, eight-, and twelve-cylinder installations are shown in Figs. 129, 130, and 131, respectively, the first being found in the 1917 Dodge, the second in the 1917 Cadillac, and the third in the 1917 Haynes. In Fig. 132 is illustrated a dual-type timer

having independent interrupter contacts for both the battery and the magneto. Apart from this feature, its construction is the same. This type is employed on the Oakland.

Delco Ignition Relay. As originally designed, the Delco ignition system was provided with a relay to produce a series of sparks for starting and a single spark when running. While this is no longer a part of the system, it is in use on thousands of cars now in

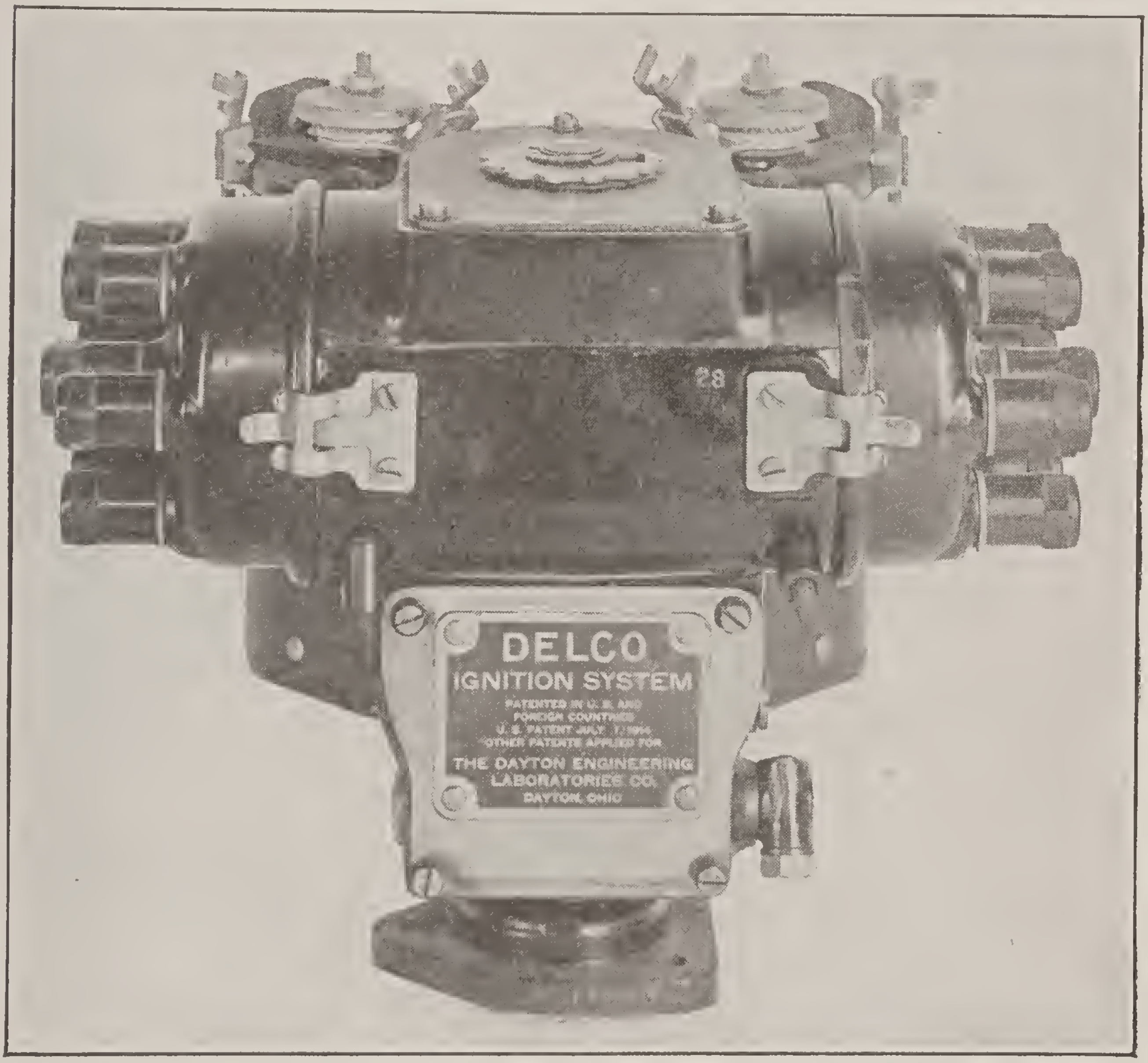


Fig. 131. Twelve-Cylinder Delco Distributor on Haynes (1917)
Courtesy of Dayton Engineering Laboratories Company, Dayton, Ohio

service. The relay itself is shown in Fig. 133, together with a diagram of its connections. It consists of an electromagnet with two windings, one of coarse wire and one of fine wire, similar to a battery cut-out. The coarse winding produces a greater magnetic effect than the fine winding and exerts sufficient pull on the movable armature when at rest to draw it toward the end of the magnet core. It is so connected that the current ceases to flow through it when

the contacts C are open. The fine winding is connected to the contacts so that it holds the armature of the relay open after the circuit of the coarse winding is broken at the contacts C, and is known as the "holding coil". Its magnetic pull is not sufficient to draw the armature down from its position of rest, but strong enough to hold it there after it has been pulled down by the other winding. A condenser is connected around the contacts C to suppress the arc and increase the speed of working. A three-way switch is provided,

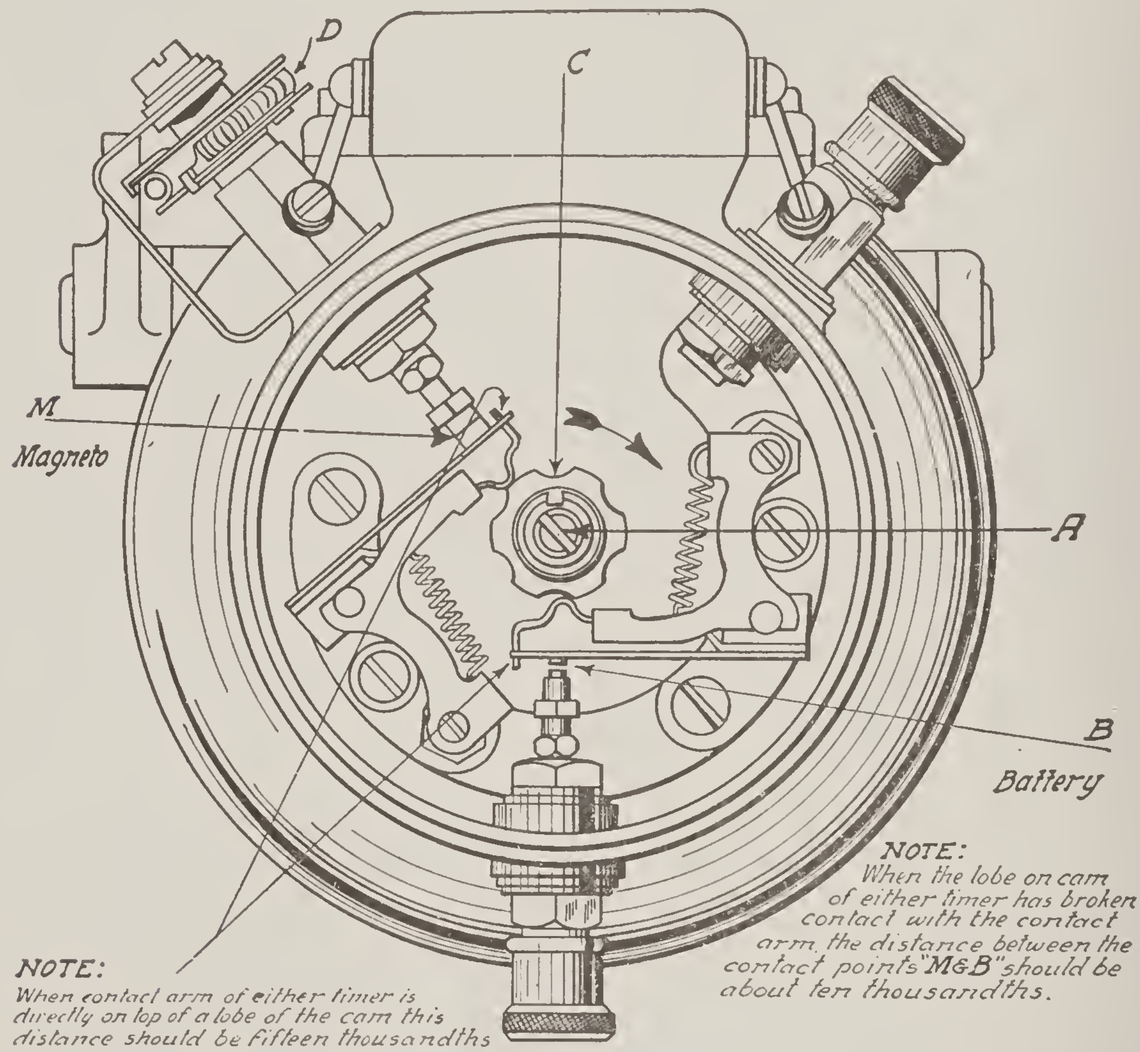


Fig. 132. Delco Dual Type Timer with Two Sets of Contacts

having a point for "starting", one for "running", and a neutral point. When on the starting point, the relay operates continuously, the same as a vibrator, and produces a series of sparks; on the running point, the fine winding of the coil is energized and the contacts held together, thus producing a single spark.

Interrupter for Higher-Speed Engines. For the extremely high-speed engines now coming into general use, a special interrupter having two sets of contact points and a three-part cam is employed (for six-cylinder motors). Each set of contacts is connected to a relay so that the circuit is closed through the two relays alternately,

thus giving each magnetic interrupter more time in which to open and close the circuit. Fig. 134 illustrates the connections of a system of this type, the interrupter being shown just above the coil, while Fig. 135 shows the complete wiring diagram.

Adjusting Delco Ignition Relay. The ignition relay is connected in the dry-battery circuit and serves to interrupt the primary-

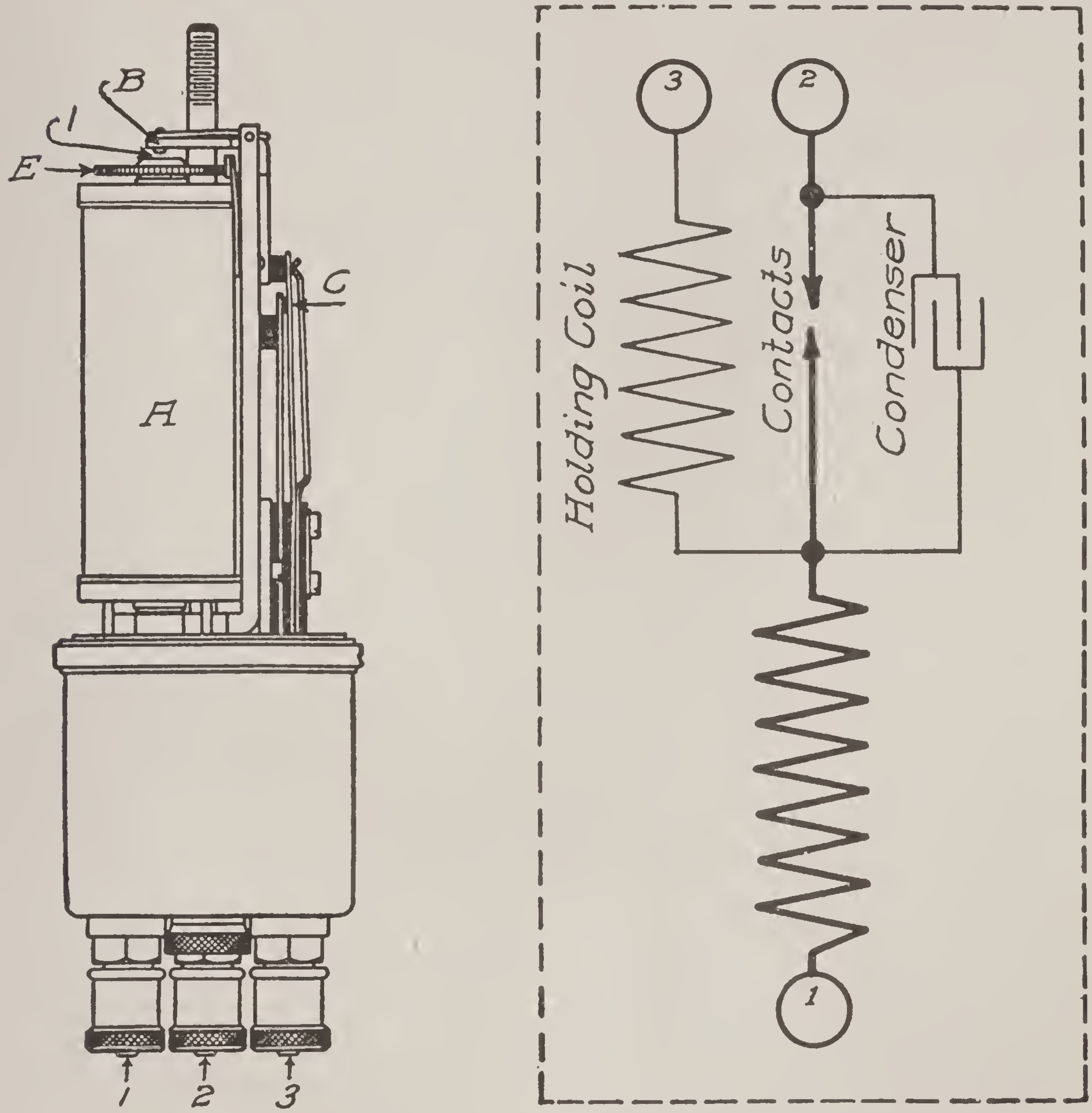


Fig. 133. Diagram of Delco Ignition Relay and Its Internal Connections
Courtesy of Dayton Engineering Laboratories Company, Dayton, Ohio

ignition circuit, inducing a high-tension current in the secondary so that a spark will occur at the plugs.

Methods of Connecting Relay. The relay is connected to the ignition coil and the distributor in two ways, as shown in Figs. 135 and 136. The operation of the relay, which varies slightly with its connection to the external circuit, is discussed as follows:

(a) (See Figs. 133 and 135 interchangeably.) The contacts C of the relay and the coil A are in series, with a special set of timer contacts on the dual distributor. When these contacts are closed (by the revolution of the fiber-timing cam), current passes through the ignition coil and timer contacts and contacts C of the relay and through the coil A, energizing the latter. This immediately causes the armature to open, thus interrupting the primary circuit and causing a spark at the plug. As soon as the circuit is interrupted, coil A is no longer energized and contacts C open again, this being repeated indefinitely as long as the timer contacts are together. This occurs

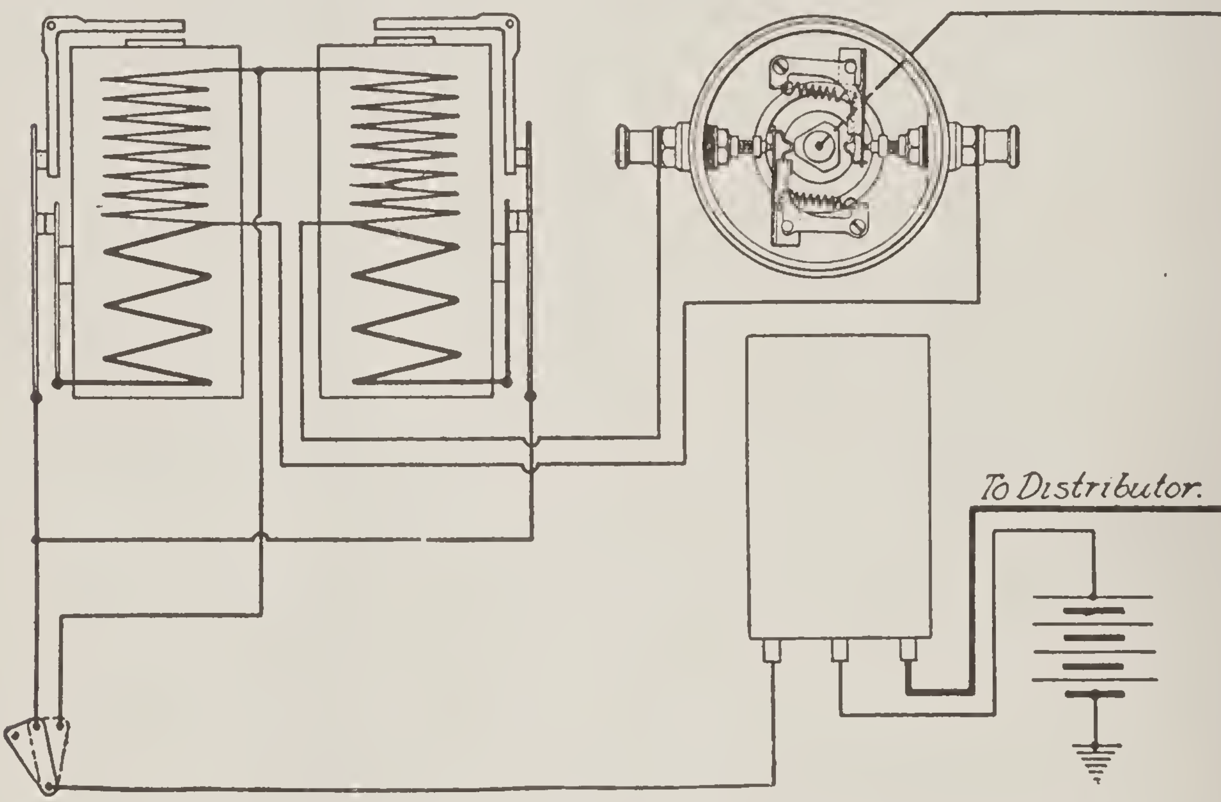


Fig. 134. Diagram of Delco Special Interruper for High-Speed Engines
Courtesy of "The Horseless Age"

only when the circuit between the terminals No. 6 and No. 7 on the combination ignition and lighting switch, Fig. 135, is open, which is accomplished by pushing the starting button. If it is desired to obtain but a single spark, as for running (the vibrating contact giving the repeated spark being simply for starting), the holding coil, Fig. 133, is energized so that when the armature touches the core, it is held there and a single spark, similar to that produced by generator or storage battery ignition, is obtained. This coil is energized when the terminals No. 6 and No. 7 on the combination switch, Fig. 135, are closed, which is accomplished by releasing the starting button.

(b) (See Fig. 136.) This is the method used in connecting the ignition relay on the Delco Junior system for 1914. The ignition

switch completes the primary circuit, and, in this manner of using the relay, the holding-coil circuit is completed through the timer

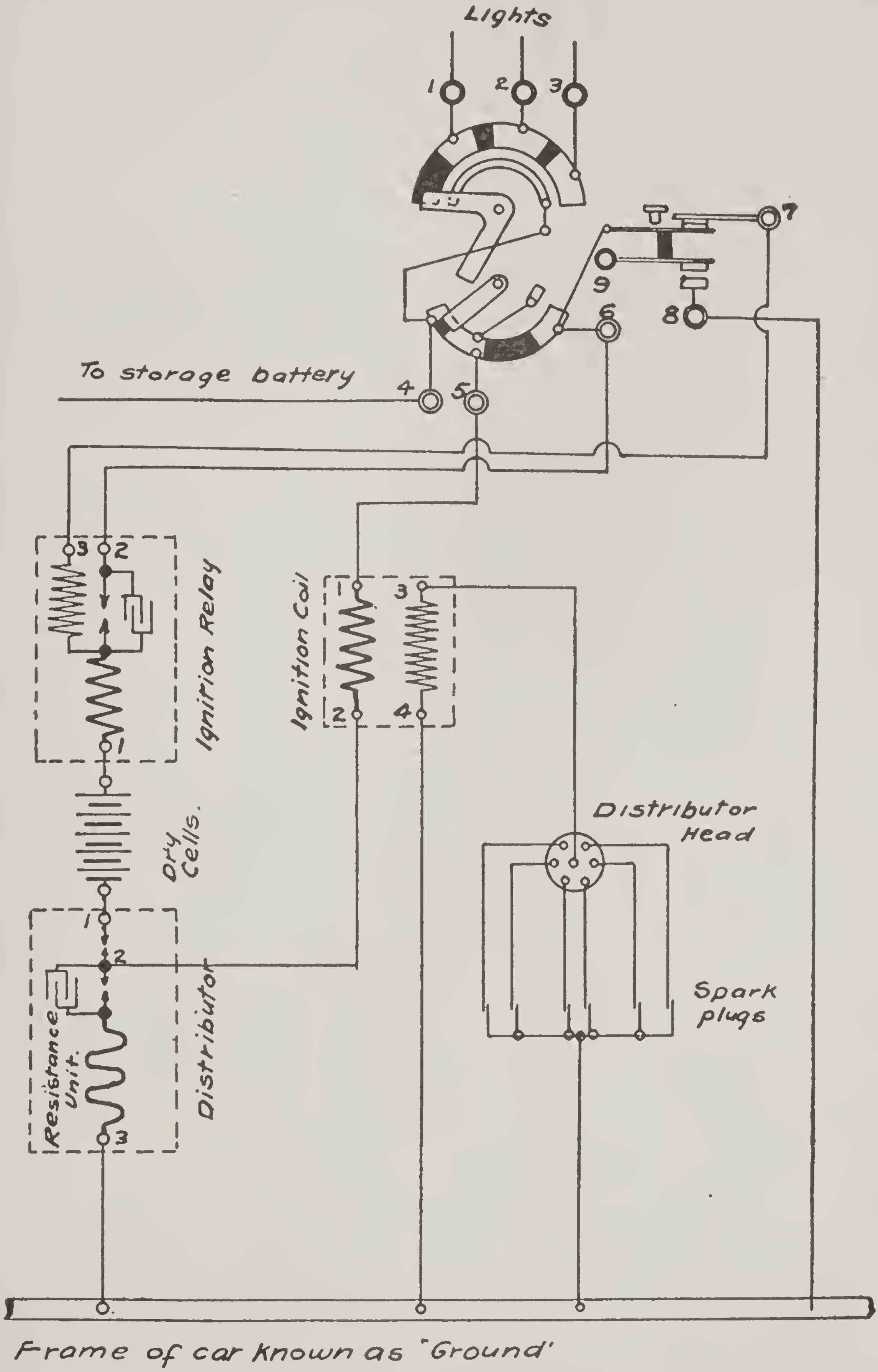


Fig. 135. Wiring Diagram of Delco Ignition System Using Relay

contacts. Therefore, a vibrating spark is obtained as long as the timer contacts are open, and the timing of this vibrating spark is obtained by the action of the contacts upon the holding coil itself.

For this reason, this method of using the relay causes much later ignition than is obtained with the method described in the previous paragraphs.

Adjustments. The following points should be borne in mind when adjusting the relay: When the armature *B*, Fig. 133, is pressed

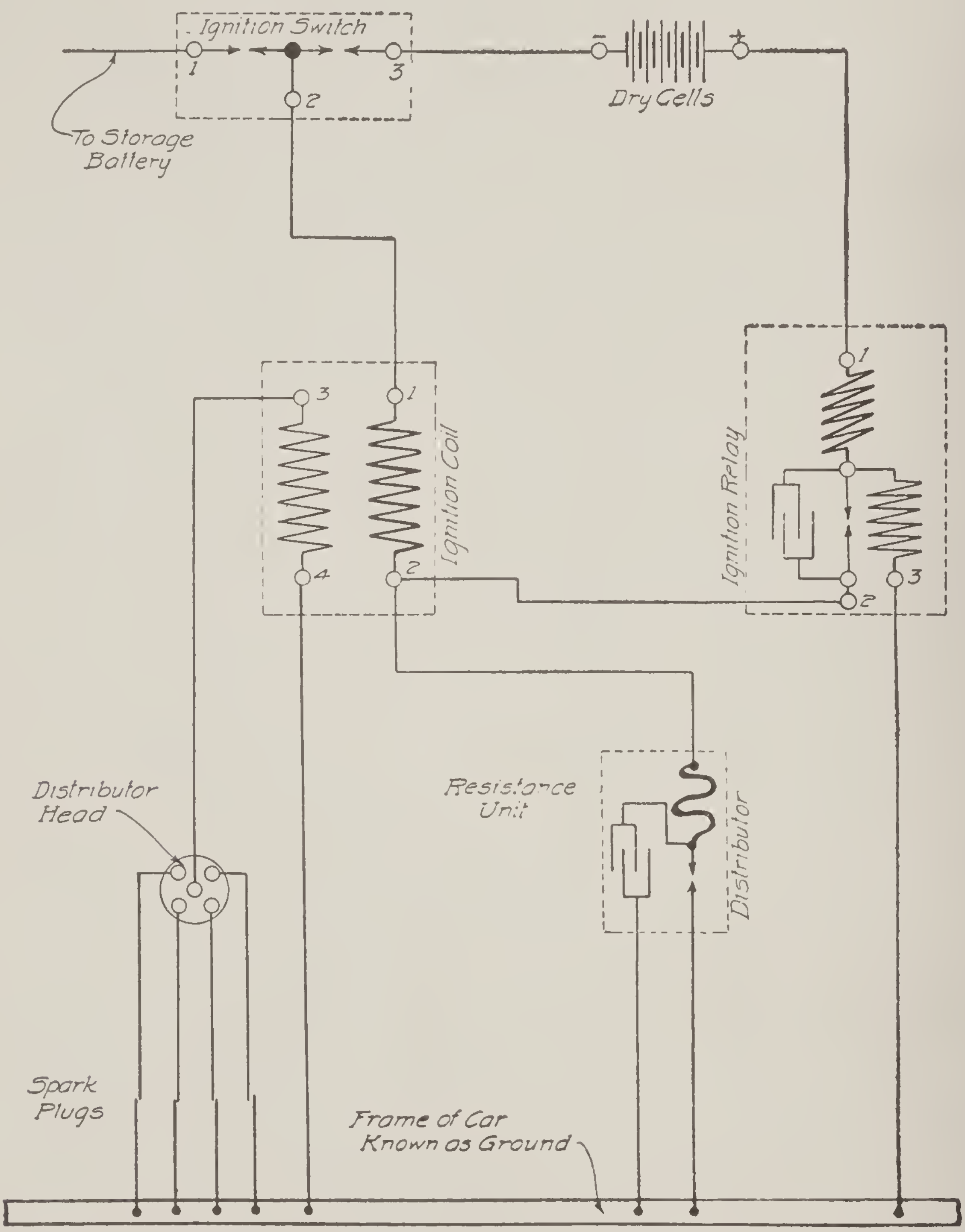


Fig. 136. Connections of Delco Ignition Relay

down with the finger, thus opening contact *C*, there should be absolutely no motion of the blade *G*, Fig. 137, carrying the lower contact. The gap at *C* should be approximately .005 inch (thickness of a piece of paper similar to, or slightly heavier than, that on which this book is printed). When blade *A* is lifted gently by hand, the con-

tacts at C should open to the same gap as before, viz, .005. The points at C must make perfect contact.

There are two adjustments to the relay: the air gap at I, Fig. 133, which increases the distance at C also; and the tension exerted by the spring A, Fig. 137, on the contacts C. Slight adjustment of the air gap I may be made, but in no event should the distance between the contacts C be increased very much over the value men-

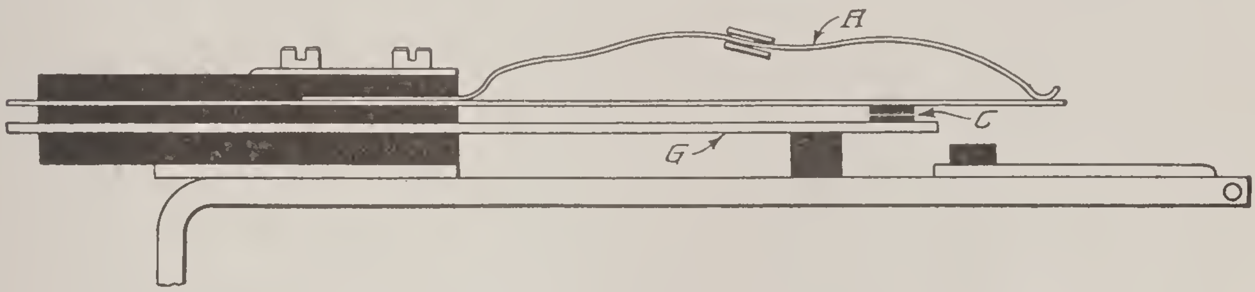


Fig. 137. Method of "Crowning" the Spring, Delco Ignition Relay

tioned above. If it is impossible to obtain a sufficiently powerful spark by adjusting the air gap slightly, it will be necessary to increase the tension of the spring A. This can be done by *crowning* the spring with a pair of duck-bill pliers. The spring is loosely held between the jaws of the pliers near the end at which it is screwed down to the relay frame, and the pliers are then moved along the spring with a downward pressure and a twist to the right, as indicated in Fig. 137. When properly carried out, this operation will cause the spring to assume a curve similar to that shown in the illustration, Fig. 138, and a very noticeable increase in the tension of the contacts

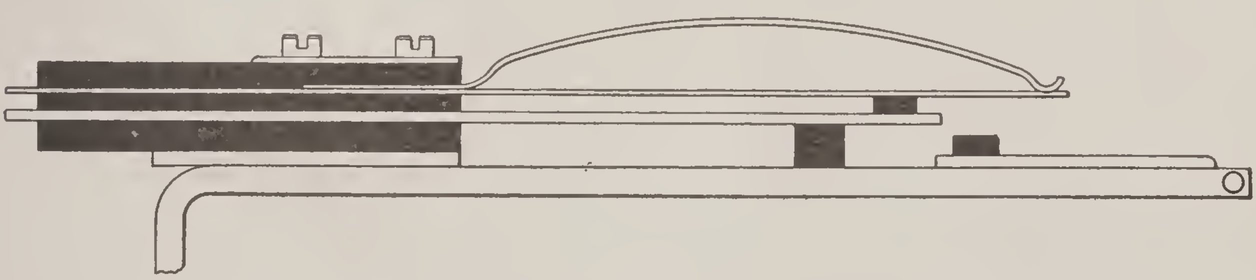


Fig. 138. How Springs Should Look when Properly "Crowned"

will have been effected. Care must also be taken to see that the armature makes a right angle (90°) and that it is free on its pin.

When properly adjusted, the ignition relay should take .6 ampere when furnishing a vibrating spark with the engine at rest, and the reading of a *dead beat* type of ammeter, similar to the Weston miniature-precision instruments, should be approximately .15 ampere when the ignition switch is thrown on.

TESTING, ADJUSTMENT, AND MAINTENANCE

Trouble Nearly Eliminated by Efficient Devices. With modern equipment, trouble from electrical sources has been decreased to an almost irreducible minimum and with a knowledge of the rudiments plus consistent observance of a few simple rules, these troubles can usually be remedied without calling in outside assistance. Causes of failure are the most important thing to remember as, with these in mind, it is far easier to trace the trouble logically than where the usual aimless hunt is undertaken on the chance of striking the cause. It must also be borne in mind that all causes of motor stoppage are not electrical. A dry gasoline tank, a plugged-up gasoline feed line or a choked carbureter, failure of a gasoline pressure-feed system, or a stopped-up air vent in a gravity-feed gasoline tank will have the same effect, though one or all of them have not infrequently been attributed to the ignition system.

Causes of Failure. Failures may be generally classed under three heads: short circuits or grounds; failure of current supply; and failure of ignition devices, such as contact breakers, distributors, vibrators, coils, spark plugs, wiring, connections, condensers, etc.

Short-Circuits. When a motor that has previously been running normally suddenly stops dead, the indication is almost invariably that of a short-circuit or ground. The difference between the two is that a short circuit takes place between two wires or other parts of the system, while a ground is the contact of a chafed wire or other exposed part with some portion of the metal foundation of the car, such as the frame or motor. The effect is the same in either case in that the current takes a shorter path and does not reach the spark plugs. Either may occur in the low- or high-tension wiring, i.e., between the contact breaker and the coil or the battery and the coil; or between the secondary side of the coil and distributor. Owing to the high voltage of the latter, grounding is more apt to result there either from a chafed wire or from a frayed end coming in contact with the motor or other metal. Failure from this cause can frequently be detected by sparking at the point of breakdown. An "open circuit" in one of the main feed cables, such as that connecting the magneto to the primary of the coil in a dual system, or the secondary of the coil to the distributor, or the battery cable in a battery system will naturally have the same effect. The cause

is usually a loose connection; sometimes, though rarely, a broken wire. If the connection has not parted entirely, irregular firing will result.

Failure of Current Supply. Failure of current supply will usually result in erratic running as the current weakens until it reaches a point where it is no longer adequate and the motor stops. But the symptoms in this case are the same as in gradual failure of the fuel supply, either through a choked carbureter nozzle, partially obstructed feed line, stopped air vent, lack of pressure, or the emptying of the tank. The motor will run by fits and starts with irregular missing at different cylinders. Defection of the contact breaker or distributor may also manifest itself either by similar erratic operation or by sudden stopping.

Weak Magnets. When the engine fires regularly on the battery but will not do so on the magneto except above a certain speed, it indicates that the magnets are weak and need remagnetizing. Heat and vibration weaken the magnets, so that on some cars it is necessary to overhaul the magneto every five or six thousand miles, whereas, on others, the magnetism shows no appreciable falling off after two or three seasons' use. With a new or recently overhauled magneto it should be easy to start on the magneto by spinning (by hand), but this is not conclusive as some engines will never start on the magneto.

Testing. *Inspection of Wiring.* Examination of the wiring and other parts of the system will usually suffice to reveal short circuits or grounds, or by making emergency connection with extra wire, proper operation through the latter indicating a failure of the parts of the wiring system thus replaced. Extra wire should always be carried on the car for this purpose. With the dual type of ignition system so generally employed, see that the zinc-containing case or the protruding terminals of dry cells are not allowed to come into contact with the metal battery box as this will cause a ground that is difficult to locate. The best preventive is a small wood container to insulate these cells from contact with any metal. Water falling on the high-tension cables will cause serious leaks that will not show in the form of sparks. Above all, every part of the system must be kept dry; sufficient precautions are frequently omitted when washing the car.

Inspection of Current Supply. To make certain that erratic operation is not due to failing current supply, a small testing instrument, such as that shown in Fig. 139, should be carried on the car. This is the Hoyt multimeter, which gives an independent ampere and voltage reading by dials on both sides of the instrument. Either may be used separately or both simultaneously. For dry battery testing an instrument with a high reading ampere scale is necessary, that shown being for the current consumption of a battery-operated vibrator coil where economy is essential. Dry cells should test at least 10 to 12 amperes to give an efficient spark, though they will frequently operate on less. An ammeter should never be employed on a storage battery. For this the voltmeter affords the best test. Full instructions for the care of storage batteries are given in the article on "Electric Vehicles".

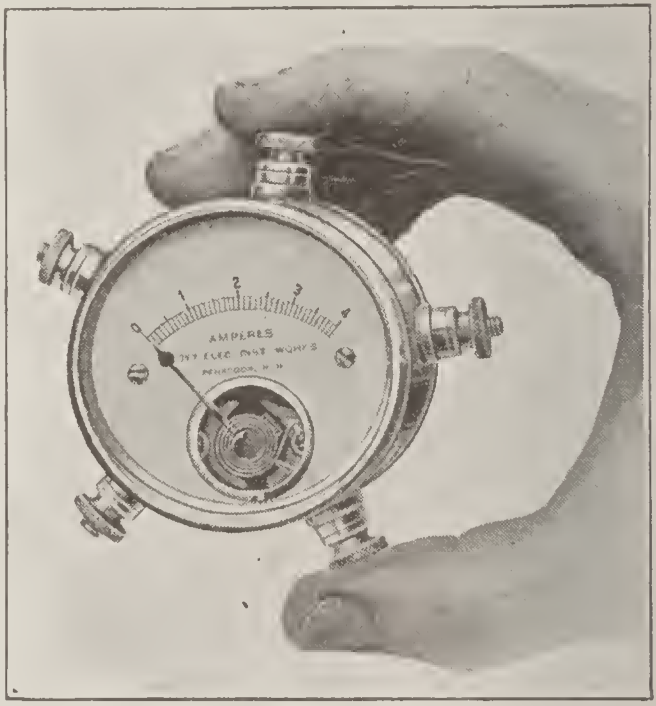


Fig. 139. Hoyt Testing Volt-Ammeter for Automobile Use

Solving Troubles. *Inspection of Contact Breaker.* Derangement of the contact breaker is almost invariably due to wear. In time the contact points will burn away unevenly, this being more rapid in older types not provided with a condenser. If not too far gone, straightening with a very fine file and adjustment will remedy this. Or they may wear down so far that the cam no longer separates them, thus preventing the secondary coil from coming into operation, as the circuit is not opened in the primary and no spark takes place at the plugs. Ample adjustment is provided to take care of this and with a little truing up of the points the trouble will be cured. These contacts will sometimes wear to a point at which the cam will still continue to open them when running at high speed, but fails to do so when the motor is cranked for starting (dual system). This provides the anomalous case of a motor running perfectly the day before and absolutely refusing to start when next cranked. It represents one of the obscure ailments mentioned,

as every other part of the system will respond to the usual tests.

Remember Effect of Compression on Spark. The effect of compression on the spark must also be borne in mind, as an apparently efficient spark with the plug out of the cylinder is not equally effective when subjected to the compression. Partial failure of the current supply is the cause in this case, due to weak dry cells or an almost wholly discharged storage battery causing a drop in the voltage. Or it may result from spark plug points that have been burned away until the gap is too great, $\frac{1}{32}$ inch being the maximum distance recommended.

Leakage at Distributor. Leakage may occasionally occur at the distributor due to the use of an excessive amount of lubricating oil which picks up carbon dust, the latter being carried around by the revolving arm until it forms a path for the high-tension current.

Spark Plugs. A broken spark plug porcelain or an internal short circuit of the plug, neither of which may be evidenced externally, will cause missing at that cylinder.

Erratic firing and a very perceptible loss of power will result from the gaps of the spark plugs being too large. With the powerful current supplied by a storage battery or by the modern magneto this takes place by the burning away of the points of the electrodes in a comparatively short time, it being nothing unusual for the $\frac{1}{32}$-inch gap to increase to almost $\frac{1}{8}$ inch in a few weeks' running. This is particularly the case with the cheaper plugs which have iron-wire electrodes; they may be adjusted with the pliers, however, until there is no longer sufficient electrode left to adjust.

Loss of power will also be occasioned by a plug that is not tight in the cylinder or where the plug itself is not tight internally. Squirt a few drops of oil around the base of the plug on the cylinder and also on the porcelain of the plug. When the engine is running bubbles will form at these points: if the plug itself is at fault, a quarter-turn of the nut holding the porcelain in place will usually seat it on the gasket and overcome any leakage at that point; in case of leakage around the thread of the plug, a new asbestos gasket under it or a slight tightening of the plug itself where of the iron-pipe thread class will remedy the trouble. Cleaning at intervals with a

stiff brush and gasoline will prevent short-circuiting through an accumulation of carbon on the porcelain and walls of the shell.

Sparking at Safety Gap. In all magnetos of the true high-tension type, the safety gap is incorporated in the magneto itself: in dual-ignition systems it is in the coil, as the latter must be protected from the battery current as well as from that of the magneto. Sparking at the safety gap is an indication that there is an opening in the circuit greater than the resistance of the secondary winding of the coil, and unless the spark bridged the safety gap, the insulation of the high-tension winding would be punctured. This opening may be a spark plug whose points are too far apart or a connection that has dropped off either at the plug or at the coil. Owing to its high voltage the current will jump any gap smaller than that of the safety gap with no perceptible difference in the firing, so that loose connections on the high-tension side seldom cause trouble until they actually separate. A piece of metal accidentally falling on it or an accumulation of any conducting material such as dirt or moisture will short-circuit the secondary of the coil through the safety gap and no current will reach the plugs. Frayed terminals in which one or more of the strands of the flexible wire protrude and touch adjacent objects are sometimes responsible for a similar result; the remedy is to wind with friction tape.

Breakdown of Magneto. On cars employing a true high-tension type of magneto, the battery system is entirely independent, as a rule, so that a fault in one never involves the other. Where failure of the magneto is not due to faulty operation of the interrupter, it may be inspected with the aid of the test lamp described in connection with starting and lighting systems. Trace the various circuits of the magneto in question; apply the points to the opposite sides of the condenser. The lamp should not light; if it does, the condenser has broken down and must be replaced. Test the primary and secondary windings of the magneto in the same way; the lamp should light in each case; if it does not, there is a break in that particular winding and a new armature will be required. In the case of the dual-type magneto there is only one winding on the armature, and many of the older makes (1910 or earlier) have no condenser. Many of these older magnetos in the cheaper grades are fitted with plain bearings and the wear of the latter may allow the arma-

ture to bind against the pole pieces, or lack of oil may cause the shaft to bind in its bearings.

When a magneto is taken apart for any reason it must always be assembled with the magnets in the same relative position as formerly, otherwise their polarity will be reversed and the magneto will be inoperative. The magnets must never be left off the machine, even temporarily, without placing a bar of iron or steel across their poles to serve as an armature or "keeper"; unless this is done, they will lose their magnetism rapidly. Remagnetizing the magnets of a machine that has become weakened through long use is a simple

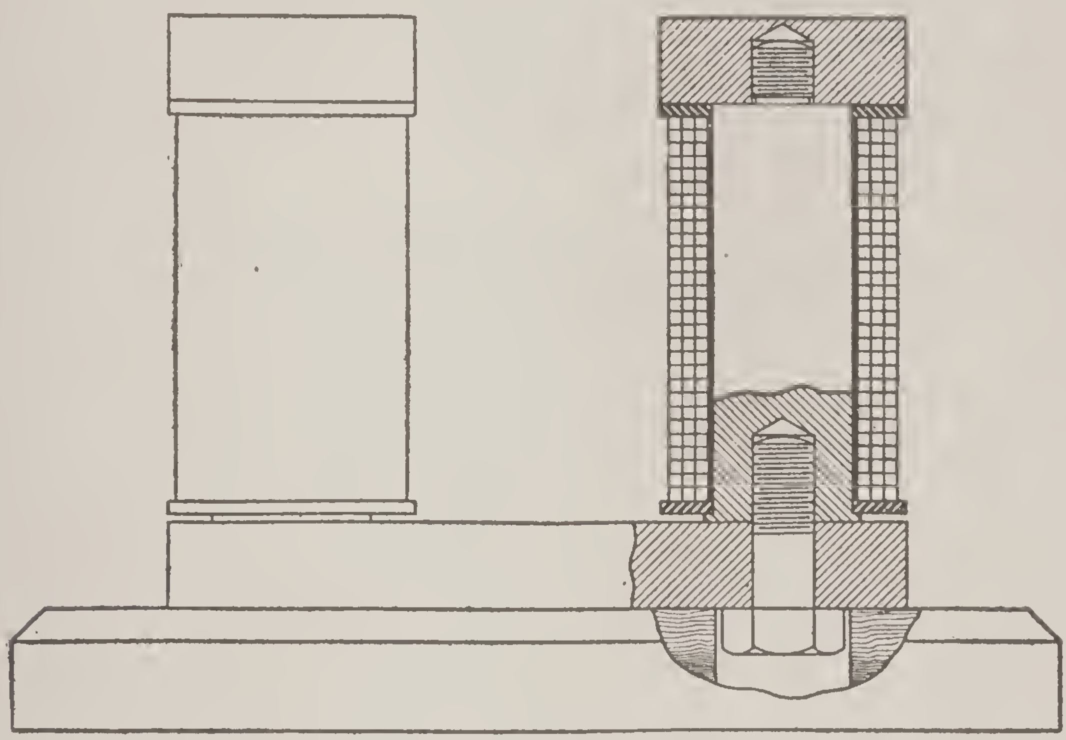


Fig. 140. Design for Magnet Recharger
Courtesy of "The Horseless Age"

process and small electromagnets for this purpose are now to be had for garage use. They will operate, of course, only on direct current.

Remagnetizing. As misfiring at low speeds may be due to causes other than weak magnets on the magneto, the strength of the latter should be tested before deciding that it is necessary to remagnetize them. With the engine running, unclip one of the spark plug leads and hold it close to the terminal. If the magneto is developing a powerful current, it will jump a gap of $\frac{1}{2}$ inch or more; should it not produce a spark at least $\frac{1}{4}$ inch long it needs remagnetizing. In recharging the magnets their original polarity must be preserved, as otherwise it will be necessary to shift their locations

in reassembling them. Accordingly, it is important that unlike poles of the permanent magnets and of the electromagnet be brought together; i.e., the north pole of the permanent magnet to the south pole of the recharging magnet and vice versa. To insure this, the current should be turned into the recharging magnet and the other magnet held freely a short distance from its poles. As unlike poles attract and like poles repel, the magnet will find its own proper position, if allowed to do so. If forcibly held against the poles of the recharging magnet regardless of polarity, the strength of the electromagnet is so much greater than that of the weakened permanent magnets that it will reverse their polarity.

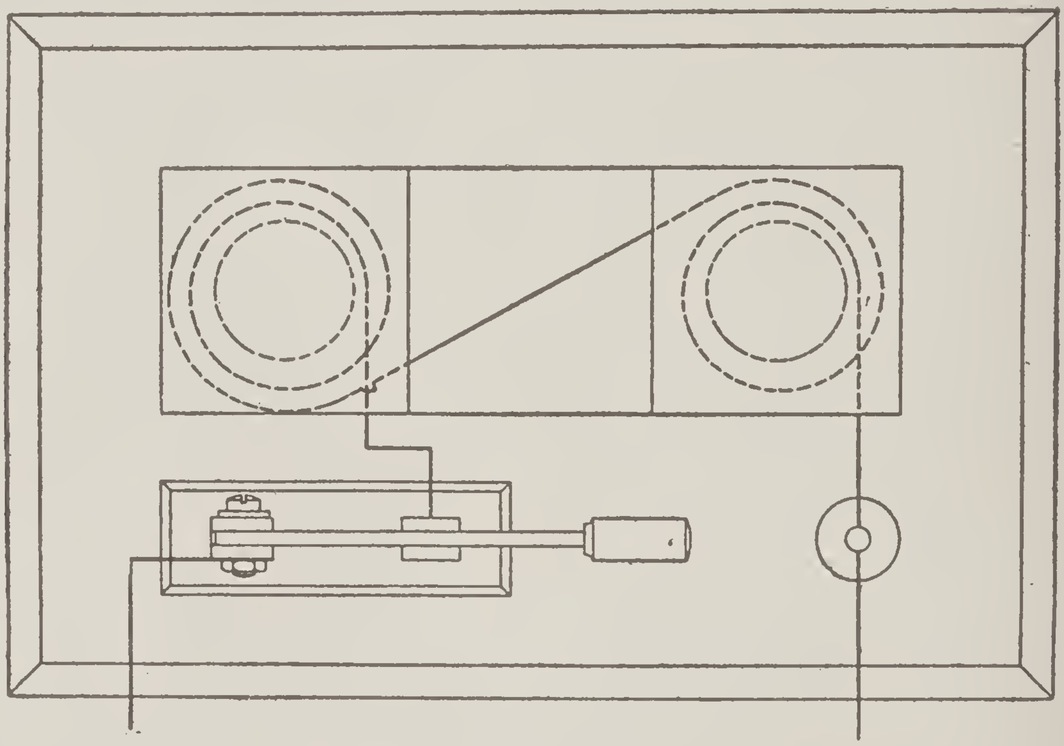


Fig. 141. Diagram of Connections of Magnet Recharger
Courtesy of "The Horseless Age"

In recharging, set the magnet on top of the charger after its polarity has been determined and rock the magnet back and forth on its pole edges a number of times; then lay it on its side with its poles away from you and, extending just beyond the far edges of the recharging magnet poles, apply a keeper to the magnet poles, switch off the current and withdraw the magnet sideways from the recharger. The keeper should remain in place until the magnets are reassembled on the magneto.

Magnet Recharger. Electromagnets designed for this purpose and built specially for garage use are now on the market, or one may be made with little trouble. The following design, Fig. **140,**

is from *The Horseless Age.* The cores of the magnet are made of soft bar steel 1 inch in diameter and 3 inches long. They are secured to a base measuring $5\frac{1}{4}$ by $1\frac{1}{2}$ by $\frac{5}{8}$ inches and are provided with pole pieces measuring $1\frac{3}{4}$ by $1\frac{3}{4}$ by $\frac{5}{8}$ inches. All contacting surfaces should be absolutely flat and square so that there will be good metallic contact over the entire surfaces. Before the wire is wound on them, the magnets must be insulated. A spool may be formed by placing a fiber ring at each end of the magnet cores, and a better job may be made by turning down a $1\frac{1}{8}$-inch bar, leaving a thin collar of the original diameter at one end. This will support the fiber ring at that end while the other rests against the pole piece. The core between the fiber rings is then insulated by wrapping with several layers of muslin which is given a coat of shellac in alcohol and allowed to dry.

The winding to be applied depends on the voltage to be used. For a 6-volt battery, wind on three layers of No. 12 double cotton-covered magnet wire; for a 110-volt circuit, eight layers of No. 22 double cotton-covered magnet wire. The ends or leads of the wire are then taped and the outer layers of the coils shellaced to make the exposed cotton insulation more enduring. Connect the coils together so that if the current flows through one right-handed, it flows through the other left-handed, when looked at from above, Fig. 141. Mount the completed magnet on a wooden base large enough to carry a single-pole switch and a binding post. The battery or lighting mains are connected to the binding post and the free terminal of the switch; the other terminal of the switch being connected to one end of the magnet coil and the other terminal of the latter to the binding post. Where designed for 110-volt current, it will be preferable to use a double-pole switch mounted on a porcelain base with two screw-plug fuses; 10-ampere fuse plugs being screwed into the sockets. The free ends of the coil are then connected directly to the terminals of the switch at the plugs and the source of current is connected to the other end of the switch. The windings specified will heat up quickly, when connected to current sources of the voltages given, so that the switch should never be left closed more than a few minutes at a time.

Where direct-current mains are accessible, the magnets may be recharged without dismounting them from the magneto. Being

flexible and well insulated, lamp cord may be used and must be wound directly on the magnets. The bared ends of the cord should be twisted together so that the two wires form a single conductor. Wrap on about fifty turns and connect this winding to the main switch through a 10-ampere fuse. Particular care must be exercised to make the connections so that the magnets will not have their polarity reversed. A current of high value will flow through the winding during the brief time that it will take to blow the fuse. While this method obviates the necessity of taking the magneto apart, the latter involves so little labor that the use of the magnet recharger usually will be found preferable, particularly where there is any doubt as to the polarity.

Care of Ford Magneto. Dirt will sometimes accumulate under the collector brush or on the collector ring and reduce the current output. As a guide to the operation of the Ford magneto, the Hoyt magnetometer, Fig. 142, has been devised. The calibration of this is purely arbitrary, the letters representing Poor, Medium, Good, and Excellent. Probably end play in the bearings is the most frequent cause of poor operation of the Ford magneto. This is due to wear of the main crankshaft bearings which permits the magnets to rotate at a greater distance from the coils than originally intended. Taking up this play or replacing the bearings is naturally the remedy. Small particles of metal may sometimes lodge beneath the ribbon terminals of the coils, or the latter may become so thoroughly impregnated with metallic dust as to ground them, making them inoperative. Cleaning and renewal of the oil in the magneto housing will remedy this. To test the coils, four or six dry cells connected in series should be used. Attach one terminal of the battery to the collector brush or insulated plug at the top of the magneto and the other terminal to the connection where the last coil is grounded to the supporting plate. Then with a piece of soft iron touch the iron core of each coil to see it if is strongly magnetized. It should take some effort to pull the iron away. A coil that does not respond properly is probably grounded. Weak magnets are occasionally

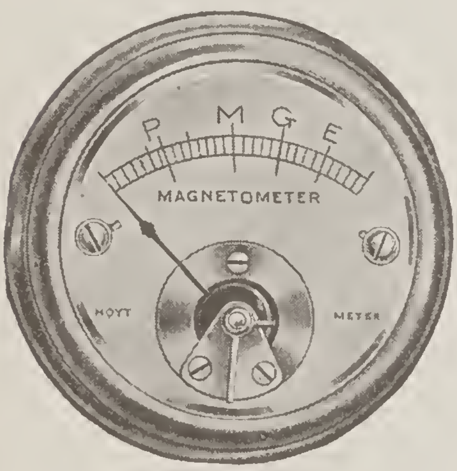


Fig. 142. Hoyt Magnetometer for Ford Cars

found to be the trouble, but this is comparatively rare, as well-made permanent magnets are usually good for years of service. When they are found, the best remedy is to replace the entire set, particularly as the cost is low.

SUMMARY OF IGNITION INSTRUCTIONS

Q. How many different systems of ignition are in use on the automobile today?

A. Generally speaking, only one, known as the high-tension system. The low-tension system used in earlier days has been obsolete for a number of years. The single classification, however, may be subdivided into several others which are known by their distinguishing features, the first being determined by the source of current supply, as magneto- and battery-ignition systems. These two classes may be divided further according to the type of magneto employed, such as the duplex, the dual, and the double-spark types. All battery systems are fundamentally the same, only differing in the type of circuit breaker and distributor employed, the mounting of the latter, i.e., whether direct driven from the engine or combined with the lighting generator, and in the type of controlling switches and auxiliary devices.

DIFFERENT SYSTEMS

Q. Why is the system generally used termed "high-tension" system?

A. Because the current must be passed through a step-up transformer or coil to impress upon it a sufficiently high voltage to cause it to jump the air gap in the spark plug.

Low-Tension System

Q. Is the old low-tension make-and-break system entirely obsolete?

A. Since about 1909, it has not been used on the automobile but is still generally employed on small two-cycle marine engines and on stationary engines.

Q. Why is it not suitable for automobile engines?

A. It will not work satisfactorily at high speeds since its time factor is limited by mechanical reasons, i.e., the inertia of the movable electrodes of the low-tension spark plugs, whereas, in the high-

tension system, only electrical lag has to be compensated for. It requires a skilled mechanic to time the spark plugs properly and they will not stay in adjustment for very long.

Q. What is the chief attention it needs as employed on marine and stationary engines today?

A. Keeping the electrodes clean; the current burns a film of oxide on the contacts and this insulates them to an extent where the low-voltage current will not pass. The timing of the plugs also needs regular attention as the hammering action of their operation tends to throw them out of adjustment. Considerable current is required for the efficient operation of the low-tension plugs, so that where used with batteries as on the motor boat, the cells frequently become exhausted in a comparatively short time.

Q. How can the low=tension plugs be adjusted to give them the proper timing?

A. Turn the engine over slowly by hand and watch the action of the plug. Its contacts should come together when the piston is three-fourths of the way up on the compression stroke; they should snap apart to cause the spark, the advance lever being in the retarded position, when the piston is at upper dead center. Provision is usually made for increasing or decreasing the length of the rod that operates the plug. If the spark is occurring too late, causing a falling off in the power, shorten the rod sufficiently by the adjustment to give the timing suggested above and lock tightly; if too early, lengthen it just enough to overcome any hammering that this would cause.

Q. Why should the plug close the circuit so long before the piston reaches upper center?

A. To give the coil sufficient time to "build up", i.e., for its core to become "saturated", or thoroughly magnetized, as the efficiency of the spark produced depends upon this.

Q. How does the coil of a low=tension system act?

A. It is a single winding of coarse wire on a very heavy core of fine iron wires, i.e., a coil having a high self-inductance. When the circuit has been closed a sufficient length of time to permit this core to become saturated and is then suddenly broken, the current utilized to magnetize the core is redelivered to the coil and causes an arc at the plug as its contacts separate. The current producing this

arc is of much greater volume and at considerably higher voltage than could be obtained by making and breaking the battery circuit without a coil in it.

Q. Does the coil ever need attention?

A. Only to see that its connections are clean and tight and that it is kept dry; owing to the solidity of its construction, failure of the coil itself is almost unknown. Test by holding one terminal of a three-cell or four-cell dry battery on one binding post and wiping the other with the wire from the other side of the battery circuit; a bright flash should result. If it does not, see if the wire has broken near one of the binding posts as this may result from vibration.

Q. Is this the only low-tension system used?

A. No. Several makes of magnetic plugs have been used in connection with low-tension systems. Each plug is a solenoid the plunger of which makes and breaks the contact electrically. No mechanism is necessary to operate the plug but a timer must be used in the circuit to close the latter slightly in advance of the time for the spark to occur. This timer is the same as that used in the primary circuit of high-tension systems employing vibrator coils, as on the Ford.

Q. What difficulty is usually encountered with magnetic plugs?

A. They seldom withstand the heat of the engine for any great length of time, so that the insulation fails. Apart from this the troubles encountered are the same as with any other system using movable contacts, i.e., dirt on the contact points, failure to make contact, broken connections, weak battery, etc.

High-Tension System

Q. Of what does a high-tension system consist?

A. The essential parts of a high-tension ignition system are: (1) a source of current, such as a dry battery, the storage battery of the lighting and starting system, the direct-current generator of the latter, or a magneto; (2) a step-up transformer or induction coil, the primary winding of which is in circuit with the source of current supply; (3) a contact breaker or interrupter to open this circuit periodically, i.e., once every other revolution for each cylinder of a four-cycle engine; (4) a distributor in circuit with the secondary winding of the coil and provided with as many contacts as there are

cylinders; (5) a spark plug for each cylinder; (6) primary and secondary cables for the respective connections, and a controlling switch to open and close the supply circuit or to change from one supply circuit to another, where both a battery and a magneto are employed.

Q. How do these essentials vary in different systems?

A. Where a battery is depended upon for the current supply, the interrupter and the distributor are usually combined in an independent device which is driven from the camshaft of the engine.

In the case of a magneto, both the interrupter and the distributor are integral with it. This does not apply to the Ford magneto which has a separate low-tension timer and uses no distributor, as there is a vibrating coil for each cylinder.

In what are commonly known as modern battery systems, the timer and distributer may be either mounted separately, as first mentioned, or combined with the lighting generator.

CURRENT SUPPLY AND APPLICATION

Magnetos

Q. How many types of magnetos are there in general use?

A. Two general classes, the low-tension and the high-tension, and various special types, such as the dual, the double-spark, the duplex, and the inductor magnetos.

Q. What is the difference between low-tension and the high-tension magnetos?

A. The low-tension magneto has only a single winding on its armature the current being generated at low voltage and transformed by passing through an independent coil, whereas the high-tension magneto generates the current in one winding and steps it up through another, both on the same armature.

Q. What is a dual magneto and why is it so called?

A. It is a low-tension type, the interrupter and distributor of which are also employed in connection with a battery for starting. It is so called because these essentials are common to both the magneto and the battery sides of the system.

Q. What is a double-spark magneto?

A. One provided with two distributors designed to produce two sparks simultaneously at two different plugs in the same cylinder.

Q. What is a duplex magneto?

A. One designed to permit of passing the battery current through the armature of the magneto to facilitate starting, the magneto and battery both acting together to produce the spark at low speeds. To accomplish this a commutator is mounted on the armature shaft and the battery connected to it, the magneto being of the high-tension type. This commutator causes the battery current to alternate in direction with that produced by the magneto so that it is said to be "in phase" with the latter.

Q. What is an inductor magneto and how does it differ?

A. An inductor is employed instead of an armature, the windings being stationary. The inductor is simply a revolving piece of metal which alternately opens and closes the magnetic circuit. In the K-W inductor magneto this winding is of copper ribbon and is placed between the poles of the inductor; in the Dixie magneto it is a conventional induction coil placed in the hollow of the magnets above the inductor.

Q. Why can a magneto not be run in either direction equally well?

A. Owing to the contour of the cam which serves to open the contacts of the interrupter. This must be designed to operate the magneto either as a "right-hand" or a "left-hand" machine.

Q. How is a magneto timed?

A. Disconnect its drive from the engine. Turn engine over by hand until the piston of cylinder No. 1 is exactly at the upper dead center on the firing stroke. Turn the armature shaft of the magneto to a point where the contacts of the interrupter are just beginning to open; the brush of the distributor which is then making contact with the distributor segment should be connected to the spark plug of cylinder No. 1. The next brush should be connected to cylinder No. 2 or No. 3, according to whether the firing order is 1- 2- 4- 3 or 1- 3- 4- 2. The armature of the magneto should be coupled to its driving shaft in the position as determined for the first cylinder.

Q. If after timing a magneto in this manner, it is found that the spark-timing lever does not give sufficient advance or retard, what should be done?

A. Remove the cover from the distributor housing of the

magneto, the piston of cylinder No. 1 being at upper dead center of firing stroke and the interrupter contacts just about to open as directed for timing. Note the relative position of the segment and the distributor brush which should be making contact with it. If the segment has already passed the brush, the spark-timing lever being at the maximum advance position, remove the distributor gear from its shaft and from engagement with the pinion on the armature shaft. Move it back one tooth (against the direction of its rotation which is the opposite of that of the armature pinion) and remesh with pinion. If this does not bring it into contact with the brush, move back another tooth. Should the distributor segment not have reached the brush when in the position as given above, move the distributor gear forward, or in the direction of its rotation, one or two teeth, and remesh.

Q. How can the various types of magnetos be identified, as installed on car?

A. The two types in most general use may be distinguished at once by their external connections. The so-called dual type can be identified by its separate coil, or transformer, mounted on the face, or the front, of the dash, under the hood, and the connecting cables from the magneto to this coil. One of these connections is for the primary of the coil, and the other is for the secondary; the other ends of both coils are joined together and connected to a common ground wire, so that the coil has only three connections. The true high-tension type can at once be recognized by the fact that its only external wires are those connecting the distributor plate of the magneto directly with the spark plugs.

Q. Of these various types, which are most commonly used?

A. The dual type will be found on most low-priced cars (except the Ford), and the straight high-tension type on higher priced cars not using battery ignition.

Q. In searching for faults, is it easier to locate trouble in one type than in the other, and is the procedure different in each case?

A. Owing to its having but a single winding on its armature, and to the fact that all of its connections are external, the dual low-tension magneto is the simpler of the two; but the exposed location of its connections makes them more subject to default than those of the high-tension magneto. The procedure differs in that failure

to operate, in the case of a dual magneto, may be caused by injury to, or the breaking of, some of these external connections; whereas, with the high-tension type, the cables are so short and so direct that the fault is likely to lie in the magneto itself.

Q. Where would be the most likely places to look for the cause of failure of a dual magneto to operate?

A. In about the order of their liability to occur, these would be as follows: broken or faulty connection at one of the coil terminals; primary or secondary cable, connecting magneto with coil, grounded through chafing or from being soaked with oil and water; ground between the dry cells and the metal battery box (this last is a not infrequent ground and is very annoying to locate, as it will occur one moment and disappear the next, owing to the vibration breaking the contact); dirt, oil, or excessive wear at the primary collector brush, and similar conditions at the brush which conveys the high-tension current from the coil to the distributor; failure of the coil through breakdown; failure of the condenser, causing the interrupter points to burn away rapidly; a break in the armature winding. All of these last are rare causes of trouble

Q. How are these faults best remedied?

A. Poor connections at the coil termimals can be overcome by baring about an inch and a half of the cable of insulation, twisting a $\frac{1}{4}$-inch loop in the end, and, after cleaning and wetting the braided end with soldering flux, dipping the loop into molten solder. The terminal nuts can be screwed down hard on these loops without opening or injuring the stranded wires, and they will make solid and permanent terminals. Where cables have become so oil soaked that the integrity of their insulation is suspected, they should be replaced, and the new wires properly supported. If either of the brushes is at fault, due to excess of oil and dirt, clean with gasoline, and true up the ends square with a fine file. Should the brushes have worn unevenly, or, in the case of the primary brush, taken on a hard, glazed surface, treatment with the fine file will remedy the trouble. When they have worn down to a point where the spring no longer holds them in good contact, new brushes and springs (attached) should be inserted.

Q. When examination shows no fault at any of these points, how can the coil be tested?

A. Disconnect the coil from the magneto, and connect to the battery terminal one wire from a spare battery of four dry cells or, if more convenient, to an ignition storage battery. Fasten the ground connection from the coil to some handy metal part of the chassis; lay the secondary cable from the coil on the chassis so that its bared end is not more than $\frac{1}{4}$ inch from the metal of the motor, or chassis. Then connect another length of wire to the opposite terminal of the testing battery. (The dry cells should be in series.) Scrape the end of this wire clean, and touch it rapidly to some part of the motor. A spark should occur every time it is touched, showing that the primary winding of the coil is uninjured, and, if the secondary is likewise uninjured, a spark should jump between the bared end of the secondary cable and the adjacent metal, every time the circuit is closed with the testing wire. The occurrence of these two sparks show the coil to be in proper working condition. If the spark occurs at the testing wire, but no high-tension spark takes place at the end of the secondary cable, it indicates that the secondary winding of the coil has broken down. Should the spark, taking place every time the testing wire is touched to a part of the motor, be very bright and hot, it is quite likely that the condenser has become punctured. Unless the failure of the secondary is due to a broken connection between the fine wire of the winding and the terminal, it must be sent to the maker for repairs. This is the case also when the condenser has been punctured. The magneto will continue to work with the condenser short-circuited, but this will cause a rapid burning away of the expensive platinum contact points of the interrupter.

Q. How is the magneto armature winding tested for a break?

A. Employ the test battery already mentioned. Touch one wire to the armature shaft, and the other to the collector end which is insulated from the shaft. A spark should result if the winding is intact. Failure to obtain a spark would indicate a break in the winding, and the armature should be returned to the maker for repairs. In making tests with a battery in this manner, always make sure that the connections from the battery have not pulled loose nor become broken, before finally accepting the lack of a spark, at the point where it should occur as conclusive evidence of a fault in the part being tested. Otherwise, a failure of the testing apparatus itself may be put down as a fault in the part being tested.

Q. Is a spark the best indication obtainable in making such tests?

A. With a fresh battery of dry cells, the self-induction of the coils tested, such as the winding of the armature or the primary of the coil, will give a bright spark that cannot be mistaken; but, if an audible indication be desired, the battery may be placed in a box and a common electric door bell, or buzzer, mounted on the box. The bell, or buzzer, must be connected in series with the testing wires, so that, when the circuit is completed, the current passes through it. Then the success of the test will be evidenced by the sounding of the bell, or buzzer, as long as the circuit is closed. In the case of the secondary winding of the coil, the spark is all that is necessary. Should a more visible signal be desired, the lamp-testing set, described in connection with trouble hunting on the starting and lighting system, may be employed. In this case; the test battery is dispensed with and the 110-volt lighting circuit used, but a 10-ampere fuse-block and fuses should be inserted in the testing circuit to guard against accidental short-circuits in handling the testing apparatus.

Q. As secondary cable is expensive, and the owner does not usually want it replaced unless absolutely necessary, how can it be tested for faults?

A. Connect the test battery to the coil, as previously described, but, instead of relying upon breaking the circuit by hand, insert a buzzer, or bell, in series, between the battery and the primary of the coil. This will give a vibrating contact, and will keep the coil working continuously. Connect the piece of cable to be tested to the secondary of the coil and support it well, clear of the ground, such as the motor or chassis. Take another piece of secondary cable and connect one end of it to the ground. Bare the other end, and pass this along the entire length of the cable being tested, very close to, or actually touching, the insulation of the cable under test. If there are any weak spots in the insulation, a spark will jump through it to the testing wire. In case a vibrating coil is at hand for making this test, it will not be necessary to insert the buzzer as mentioned.

Q. What is likely to result when there are weak spots in the insulation of the secondary cables?

A. The high-tension current will escape through them to the ground, because of the nearness or actual contact of the secondary

cable with the motor cylinders or other metal parts. This leakage will be neither visible nor audible, unless the insulation is very bad, and the failure to fire will usually be attributed to the spark plug instead.

Q. Should primary cables be tested in the same manner.

A. It is not necessary; as, unless the insulation is actually worn off, there will be no escape of current, owing to its low voltage. Where solid instead of flexible primary wire is employed, as on some old cars, or where the owner has made replacements, a test for a break in the wire itself under the insulation may be made with the aid of the battery and buzzer alone.

Q. Are the causes of failure similar in a true high=tension magneto?

A. No. As the primary-generating winding and the secondary, or high-tension winding, are both on the armature of the magneto itself, and all connections, except the high-tension leads from the distributor to the spark plugs, are made internally, there are no outside cables, terminals, or coils to default. Unless the repair man has become proficient in testing electrical apparatus and has familiarized himself with the construction of the high-tension type, he will find it preferable to refer to the manufacturer any cases of trouble in this class of apparatus. In fact, the maker usually absolves himself from any responsibility in case a magneto of this type has been taken apart. Even where the repair man is capable of dismantling and testing this type of magneto, its repair would ordinarily be beyond his facilities, so that it is better to refer it to the maker at once.

Q. Are there any faults, peculiar to the "duplex" or to the "double=spark" types of magnetos, which are not encountered in the others?

A. In the case of the duplex type, there may be a failure to work of the battery connections or of the battery commutator on the armature shaft, i.e., the commutator which throws the battery current into phase with the armature current of the magneto when starting. Since the advent of the self-starter, this type of magneto has had no particular advantage to recommend it, and will be found only on older cars. As the only difference between the double-spark and the usual magneto is a duplication of the distributor to give two sparks in the cylinder instead of one, its treatment is the same.

There are simply two distributors to maintain instead of one. This type is also of limited application and will be found only on comparatively few cars of several years back.

Q. Why is it important that the magneto be accurately timed?

A. Unless the spark occurs at exactly the right moment, the motor will not operate efficiently. If it occurs too soon, the explosion will tend to retard the piston; if too late most of the power that would have been derived from the compression will be lost. As the lag, i.e., the time intervening between the moment the contact points are opened at the interrupter and the occurrence of the spark at the plug, is negligible in the magneto, it must be more accurately timed than the old battery and vibrator-coil system.

Q. Does the magneto ever fail to operate through lack of oil, and what attention should be given to its lubrication?

A. Prior to 1910, when some of the lower-priced magnetos were made with plain bearings, this naturally occurred, but, with the adoption of high-grade annular ball bearings for the magneto shaft, it is practically unknown. However, even the high-grade ball bearing will not operate without lubrication. If it runs dry, the balls are apt to rust and ruin the bearing. Most of these bearings are packed with vaseline, or similar light grease, when the machine is assembled and require no attention during the life of the average car. Where this has not been done, as on some of the older machines, a few drops of fine sewing-machine oil once a year will suffice. The pivot and roller of the contact-breaker arm also should be oiled once or twice a year with one drop of oil to each, using a toothpick.

Q. When taking a magneto apart, as where it is necessary to remagnetize the fields, why is it of the greatest importance to reassemble them in the same way?

A. Unless this is done, the polarity of the fields will be reversed and the machine will not generate properly. The maker usually identifies the polarity of the fields by marking the magnets so that it is easy to reassemble them in the proper manner. See the illustration of the Eisemann magneto, Fig 103.

Q. When remagnetizing the field magnets of a magneto, why is it important that their polarity should not be changed in the process?

A. The effect would be exactly the same as if the remagnetizing

were carried out properly, so far as their polarity were concerned, and then the magnets were put back the wrong way. The machine would not generate. For example, the marking on the side of the Eisemann magneto indicates the north pole of its fields. If in remagnetizing, this side of the field is made the south pole, and it is then correctly assembled, it will be evident that the polarity of the entire field has been reversed.

Q. In the case of the dual magneto, how can trouble, caused by the grounding of the dry cells against the metal battery box, be overcome?

A. By making a tight-fitting wooden box to hold the battery, this wooden box fitting inside the metal one.

Q. Does the care required by an inductor type of magneto vary from that necessary for other types?

A. No. So far as its outside connections go, it is the same. That is, in a dual type installation, using an external coil, or transformer, the causes of trouble and their remedies will be the same as in any dual system, as already given; and this also applies to the high-tension dual type.

Q. In the order of their occurrence, what are the commoner causes of failure of the magneto, due to wear of its parts?

A. In practically every case of failure of the magneto that is not otherwise apparent at a glance, an inspection should always be made of the contact points in the breaker box. Unless they open properly when the cam strikes the lifter, no current reaches the outside circuit and the coil is not energized. Next, inspect the contact of the collector brush; see that it is clean; that it is making good contact over its entire surface; and that its spring is holding it firmly in place. After this, inspect the distributor.

Q. How often should the contact points in the breaker box require attention?

A. This will depend upon the type of magneto, and when it was made. On some of the earlier types, prior to 1909, no condensers were used on many of the lower-priced magnetos, and the points required attention every 3,000 or 4,000 miles. Others will run two or three times this distance without requiring attention. If, when the points have been found in poor condition, they have not been properly trued up and adjusted, they are apt to require attention

again much sooner, as any irregularities in their contact faces will cause them to burn away much more rapidly.

Q. As the platinum contacts of the magneto breaker box are expensive, how far down can they be allowed to wear before it is necessary to replace them?

A. This will depend upon the amount of adjustment provided. As long as there is sufficient platinum left to provide a true surface on each contact point, it will not be necessary to replace them if they can be adjusted so that the cam opens and closes them properly.

Q. Since the magneto-armature circuit is normally closed upon itself and only opens when a spark is required at one of the plugs, how is the magneto ignition shut off?

A. By short-circuiting the armature around the contact points. Instead of opening the entire ignition circuit, as in the case of a battery where it is necessary to save current, the generating part of the circuit is closed. This is true of all high-tension magnetos.

Q. When the contact points of the interrupter of the magneto fail to separate, what is the result?

A. The armature remains short-circuited upon itself throughout the revolution, and no current reaches the outer circuit, so that the engine will not fire on the magneto at all.

Q. What is the result when the contacts open but the gap is not wide enough?

A. Erratic missing, probably at all speeds, but more pronounced when the engine is running slowly. The increased kick given the movable contact arm by the cam, when the engine is running at a higher speed will cause it to fire more regularly.

Q. What happens when contact points are separated too far?

A. The missing is likely to be more noticeable at high speeds than at low speeds; as, when turning very fast, the looseness of the movable contact arm may prevent it from closing the circuit again in time for the next cylinder to fire.

Q. What is the proper distance for the setting of the contact points of the magneto interrupter, or breaker box?

A. Approximately $\frac{1}{64}$ inch, or the equivalent of an ordinary sheet of paper. When the points are properly adjusted, it should be possible to insert the paper between them and move it around without binding.

Q. How are the contact points usually adjusted?

A. Practically every magneto manufacturer now supplies an adjustment gage, which serves also as a screwdriver or small spanner, according to the construction of the interrupter. The thickness of the metal represents the distance that the contacts should open. In all except the old types produced several years ago, the interrupter may be removed without the use of any tools, and the adjustment made without the necessity of removing the magneto from its bedplate. The following instructions cover the Eisemann dual type in this respect, and are typical: "Insert from behind through the hole in the plate carrying the make-and-break mechanism, the metal adjuster which we supply with every magneto: by means of a flat wrench hold the nut on platinum screw (contact) and turn the platinum screw upward or downward until there is a gap of $\frac{1}{64}$ inch between the contacts, i.e., a piece of paper must pass between them without getting jammed", Fig. 143.

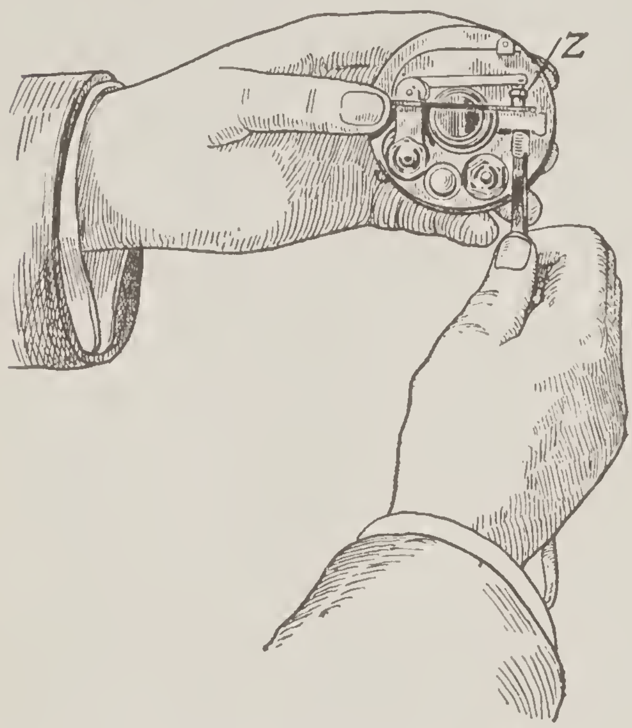


Fig. 143. Method of Adjusting Magneto Contact Points

Q. How often should the magnets of a magneto need remagnetizing?

A. No definite time nor average can be given for this. In some cases, the makers state specifically that the magnets will never need remagnetizing during the entire life of the machine, unless they are taken off and allowed to stand without a "keeper", i.e., a piece of soft iron placed across the pole pieces, the magnets themselves being placed in their usual relation as when on the machine. In others, it has been nothing unusual to require this once a year, or after 6,000 to 10,000 miles running.

Q. How can it be determined definitely whether the magnets actually need remagnetizing or not?

A. Many cases of weak or faulty ignition are attributed to loss of strength in the magnets, when they are actually due to some-

thing else. Before deciding that the magnets themselves are at fault, every part of the system should be gone over thoroughly. See that the contact points are clean and true, and that they are properly adjusted; that the low-tension collecting brush, or contact, is clean and is making good contact; also, that the distributor is clean. Inspect all terminals and connections. Test the condenser. Disconnect one of the spark-plug leads, keep it away from any metal part of the chassis and, with the engine running, note whether a spark occurs at the safety gap. In a high-tension magneto, this gap is ually located in the hollow of the magnets back of the distributor; in a low-tension type, having a separate coil, it is usually on the coil. Take the spark-plug lead which has been detached (engine running) and approach its metal terminal gradually to the spark-plug end, or to some metal part of the engine, noting the maximum distance that the spark will bridge. If this is one-quarter inch or more, the magnets are not at fault.

Q. When there is no question but that the magnets are the cause of faulty ignition, how can the magnets be remagnetized?

A. With the aid of a small electromagnet, as described in the chapter on this subject. Care must be taken to see that the polarity of the magnets is not reversed in the process, as this will render the magneto altogether inoperative.

Q. How is the ground connection made in a magneto?

A. One side of the winding of the armature in a low-tension type, and of both windings, i.e., the primary and secondary are grounded by being electrically connected directly to the core of the armature itself, in the high-tension type. The fastening of the magneto in its bedplate on the engine, completes this ground connection.

Q. Is it ever advisable to insert paper liners, or liners of any material, between the magneto and its bedplate?

A. If on an old car, it is necessary to resort to liners or shims to correct the alignment of the magneto with its driving shaft, nothing but thin sheets of brass or iron should ever be employed, as the use of any insulating material for this purpose would break the ground connection and prevent the magneto from functioning properly. But even on old cars, where the lack of alignment of the magneto with its shaft is such as to be plainly perceptible to the

unaided eye, the Oldham coupling usually employed on the driving shaft, allows sufficient play to compensate for this. Any lack of alignment is more likely to be due to carelessness in replacing the magneto after it has been removed from the engine for attention, than to any fault in the placing of the bedplate and driving shaft.

Q. What will be the result of the magneto being lined up incorrectly?

A. The universal coupling is apt to wear badly, and the side pressure, which the lack of alignment causes, may not be taken care of entirely by the coupling, so that the pressure has to be taken in part by the magneto shaft and its bearing. This will result in undue wear of the bearing and, in time, may permit the armature core of the magneto to strike the pole pieces, or sides of the tunnel, so that it will jam. On many of the higher-priced cars, a flexible coupling, consisting of leather discs, is employed for the magneto drive.

Q. Which is more likely to occur, separation of the points by too great a distance or their coming together so that they do not open?

A. The result of wear will usually be to increase the distance between the points, but the writer has experienced the opposite on an old car where the cam apparently wore down faster than the points and prevented their opening. This was probably due to improper hardening of the cam itself or to the fact that the roller was harder than the cam. Many of the later models do not employ a roller in the movable contact arm, the cam striking directly against a projection on the arm itself (see Eisemann interrupter, Fig. 143). An example of the roller type, is the K-W interrupter, Fig 69.

Q. Is it possible for the adjustment of the contact points to wear to such a degree that the magneto will fire the engine at high speeds, but not at all at low speeds?

A. Instances of this nature on old magnetos have proved a puzzling cause of ignition failure. The extra kick of the cam at high speeds would separate the points, whereas at low speeds they remained together.

Q. Inspection having shown other parts of the ignition system to be in good order, how can it be determined whether the magneto itself is at fault?

A. Run the engine on the battery, and switch from battery to magneto while the engine is running at a good speed. If the magneto

is not operating properly, the difference in running will be perceptible immediately; in case the contact points are not opening, the explosions will cease at once upon throwing the switch to "magneto".

Q. What is meant by "ignition timing"?

A. A four-cycle motor is so-called because there are four parts to each cycle: viz, suction, compression, firing, exhaust. It is evident that ignition is necessary only at one part of the cycle and that the spark must occur at a certain time with relation to the carrying out of that part of the cycle. Determining the point at which the spark is to occur in that part of the cycle is usually referred to as the "timing of the spark", or as the "ignition timing".

Q. Is it necessary that this be carried out with precision?

A. In the high-speed automobile motors of the present day, it must be extremely accurate with relation to the movement of the piston and must be exceedingly rapid in action; otherwise, the efficiency of the motor would suffer greatly. In the slower-running motors with fewer cylinders, of several years ago, neither of these factors was of such great importance; but the present-day high-speed multi-cylinder motors could never be operated satisfactorily on ignition apparatus of the type familiar on 1910 models, for example.

Q. Why would a variation or a lack of precision affect the running of the motor?

A. Speeds are now so high that the time factor is reduced to exceedingly small fractions of seconds. For example, take a high-speed four. It turns at 2500 r.p.m.: as there are two explosions per revolution in a four-cylinder motor, this would mean 5000 sparks per minute, or one spark every .012 second. This is cutting time pretty fine, but in a modern twelve-cylinder motor, it is finer still. Say the twelve runs at 3000 r.p.m.: in a twelve there would be six explosions per revolution, requiring 18,000 sparks per minute, or one for every .0033 second—thirty-three ten-thousandths of a second—an incredibly brief space of time in which to carry out a combined mechanical and electrical function.

Q. How is this extreme accuracy obtained?

A. By the use of precision machine work in the distributor, approaching that of a fine watch, and a great amount of "advance" to compensate for any lag in either the mechanical or electrical functioning of the apparatus.

Q. What is meant by "lag", and what is the difference between mechanical and electrical "lag"?

A. As the term implies, lag is delay: in other words, it is the time elapsing between the moment a part begins to move and the actual moment at which it moves and makes contact or carries out the function for which it is designed. Mechanical lag is due entirely to the time necessary to overcome the inertia either of a part that is stationary or of one that is moving in another direction and whose direction must be reversed. Electrical lag, on the other hand, is the time elapsing between the moment that current is switched into a piece of electrical apparatus and the moment that the apparatus actually operates. This will appear strange at first sight in view of the universal belief that anything electrical operates so swiftly that it is next to impossible to measure the time required. This is true when nothing more than the passing of a current of electricity from one point to another is concerned, but when actual work must be performed by the current, the time required is not only measurable but it may be so perceptible as to have a decided effect upon such extremely rapid functioning as that mentioned. For example, when the work to be performed by the current consists of magnetizing the core of a coil, as is necessary in automobile ignition, the time element is quite perceptible, as may be noted by referring to the oscillograph of the spark produced by an induction coil, Fig. 95. A coil having the characteristics shown by this oscillograph would be worthless on a modern high-speed motor.

Q. How is this lag compensated for?

A. By advancing the moment that contact is made outside of the cylinder to an extent that will insure the occurrence of the spark in the cylinder at the proper moment. In other words, the current is started on its way sooner with relation to the movement of the piston. This is generally referred to as "advancing the spark".

Q. What is the proper point, in the travel of the piston on the compression stroke, for the ignition spark to occur?

A. Exactly at the upper dead center just before the piston starts downward again. The compression is then at its maximum, and firing the charge exactly at that moment results in the production of the greatest amount of power. The compression falls off very rapidly the moment the piston starts down on the power stroke, so

that in a high-speed motor, the loss of even a very minute fraction of a second causes a considerable loss of energy.

Q. What will happen if it occurs too soon?

A. This will depend largely upon the type of motor and upon how much in advance of the proper time it actually occurs. In a slow-speed type running well below its normal r.p.m. rate, as where a motor with a normal speed of 1000 r.p.m. is slowed down to 600 r.p.m., owing to climbing a hill, advancing the spark to its maximum will cause hammering or pounding in the cylinders, indicating that the explosion is taking place before the piston reaches upper dead center and, consequently, that most of its energy is being expended against the rising piston, instead of helping thrust it downward as it should. When running at its normal rate, the piston speed of such a motor would be sufficient for the piston to have reached upper dead center before the burning gases had time to expand, so that their entire output of energy would be expended in producing power. In high-speed multi-cylinder motors with their diminutive cylinders and light moving parts, the piston speed is so great that even the maximum advance in the ignition timing would have no effect, even as the lowest speed of which the motor is capable.

Q. What is the result when the spark occurs too late?

A. The piston has already started on its downward stroke; the point of maximum compression has been passed, so that the full benefit of the compression is lost, and with it, a large part of the energy that would otherwise have been utilized.

Q. Has running with a late spark any other effect on the motor?

A. Yes. The gas in the combustion chamber is ignited so late that it continues to burn after the exhaust valve is opened. As the heat units it contains are not utilized as power, they are retained longer in the cylinder in the form of heat; the water jackets are compelled to absorb 50 per cent more of the heat than they should; and the whole motor is said to "run hot" or to "overheat". The late combustion of the gases does not permit of sufficient time for the normal amount of heat to escape by way of the exhaust, so that there is still burning gas in the combustion chamber when the exhaust valve closes.

Q. What other term is used in referring to a late spark?

A. Retarded ignition, or a retarded spark, meaning one that occurs later in the firing part of the cycle, i.e., later with relation to the travel of the piston itself. An *early spark*, or advanced spark, is set to occur or rather *start* to take place well before the piston has reached upper dead center on the compression stroke. The time of ignition is always based on its relation to the position of the piston, though frequently referred to in terms of degrees on the periphery of the flywheel. This is done for greater convenience in setting the ignition, as the timing of the valves is always marked on the rim of the flywheel.

Q. Why is it necessary to have the ignition occur later at one time than at another?

A. To permit of starting the motor, especially by hand. The time of ignition is advanced to compensate for the extremely rapid travel of the piston, and is designed to cause the spark to take place just as the piston reaches upper dead center on the compression stroke. In high-speed motors this advance amounts to as much as 1 inch of the stroke. It will, accordingly, be evident that if an attempt be made to start the motor with the spark advanced, ignition will take place before the piston reaches upper dead center and the motor will kick back.

Q. How much allowance is usually made for retarding the time of ignition?

A. In the ordinary type of motor in which the speed does not exceed 1500 to 1800 r.p.m., it is customary to have the latest timing allowed coincide with the upper dead center position of the piston. In some cases, the spark may be retarded to take place after the piston has traveled a short distance down on the firing stroke, or about 5 degrees to 7 degrees on the rim of the flywheel. In the majority of cases, however, "extreme retard" is at the upper dead center of the piston.

Q. How is the time of ignition, or "spark", advanced and retarded?

A. The timer, in the case of a system using vibrator coils, and the distributor, in all systems using one vibratorless coil, consists of two parts. In the case of the timer, the four contacts for a four-cylinder motor are set into the inner periphery of a circular casing and a single revolving contact, mounted on the camshaft, passes

over them consecutively, sending the current through the primary winding of each of the induction coils in rotation. These coils are connected to the spark plugs of the different cylinders in the proper firing order. While this outer casing of the timer is normally stationary, it may be moved part of a revolution with relation to the position of the revolving contact. For example, if the moving member in its revolution were within 20 degrees of touching the contact corresponding to coil and cylinder No. 1, and then the casing were revolved 20 degrees in the same direction as that in which the contact is moving, it will be evident that the meeting, or contact, of the two will take place that much later, and the occurrence of the spark in the cylinder will be correspondingly delayed. If, instead of being moved away from the revolving contact, the housing is revolved against the direction of rotation of the contact, the two will come together that much sooner and the spark will be advanced, or occur earlier. This housing of the timer is connected by means of linkage with the spark lever under the steering wheel.

In the case of the distributor, the principle is exactly the same, except that the current is sent in turn by each one of the contacts, through the same induction coil, instead of having a coil for each cylinder. The method of accomplishing this result is also varied: in many magnetos the distributor consists of a revolving block carrying a single contact, while a carbon brush for each cylinder bears against it. In most of the battery-system distributors, the arrangement is very similar to a timer, but the construction and insulation are naturally carried out in very much better fashion.

Q. What is meant by an advance of 30 degrees for the ignition?

A. That the difference between the point of extreme retard, usually upper dead center of the piston, and that of maximum advance or earliest ignition for high speed, represents 30 degrees on the flywheel. Just what this corresponds to in distance traveled by the piston naturally depends entirely upon the diameter of the flywheel.

Q. What is meant by the magneto setting point?

A. This is a line inscribed on the flywheel in the same manner as the usual marks for the valve timing of the motor. There is a corresponding dead line, or pointer, on the crankcase, with which these lines on the flywheel are registered to check the valve timing

and the setting of the magneto. When the magneto-setting lines on the flywheel is directly opposite the dead line, or pointer, on the crankcase, the piston of cylinder No. 1 should be at upper dead center exactly on the compression stroke, i.e., on the previous down stroke, it has drawn in a fresh charge, and when the piston again reaches upper dead center it has completed compressing this charge, so that the cylinder is then ready to fire. With the piston of this cylinder at the position in question, the contact points in the breaker box of the magneto should be just opening.

Q. How is the ignition timing advanced or retarded on a magneto?

A. The magneto breaker box may be moved part of a revolution, with relation to the contact points, in exactly the same manner as previously described for a timer or distributor. This alters the relation of the cam which opens the contact points to the latter so that their separation takes place earlier or later, in accordance with the direction the breaker box is rotated.

Q. Why is it that a motor may be cranked by hand with the spark lever in the fully advanced position when starting on the magneto, and why can this not be done safely with a battery?

A. There is less actual advance in the time of ignition, as supplied by the magneto, represented by the movement of the spark lever. That is, moving the spark-advance lever to its maximum does not cause so much advance in the actual timing of the ignition when connected to the magneto for starting, as it does when connected to the battery. The speed of the magneto itself is responsible for a considerable advance in firing time when the motor is running, whereas the battery ignition has a fixed speed of operation, regardless of whether the motor is being turned over by hand or is being run full speed. Moreover, as the usual magneto setting point is upper dead center, the spark does not actually occur until slightly later, when the motor is being cranked slowly, so that, while the spark lever may be in the advanced position, the actual occurrence of the spark is not perceptibly earlier than it would be with the lever fully retarded. This makes it possible to crank the motor with the lever fully advanced on the magneto, without any danger of a backfire. This is not true to the same extent with the Ford magneto as with other types, owing to the great number of pole pieces and arma-

ture coils that it carries. With a battery, however, the occurrence of the spark is just as rapid at low speeds as at high, so that attempting to start on the battery with the lever fully advanced will invariably result in a vicious back kick; the whole force of the explosion is exerted against the rising piston. As there is a greater amount of lag in the ordinary battery system than there is with the magneto the movement of the spark lever represents more actual advance, as this is necessary to provide for the time lost in the operation of the system. This, however, applies only to old battery systems, such as the dry cells used in connection with the magneto in a dual systems and not so much so to the so-called modern battery-ignition systems which are practically as rapid as the magneto.

Q. What is meant by fixed ignition?

A. The time of ignition is not variable by means of a spark-advance lever. Only a magneto is employed (true high-tension type) for ignition and it is set to fire at the maximum advance at all times when running. Provision is usually made for retarding the time of ignition to allow for hand starting, though this is not always the case, as it is not absolutely necessary (see answer to previous question). Otherwise, the ignition is always advanced to the maximum and there is no lever on the steering wheel for varying it. This type of ignition system has been very generally employed abroad and, more particularly in France, on commercial vehicles, such as cabs, but has never found any favor here. It has not been used in this country, except on a very few makes of cars, and then only for the models of one or two seasons, the latest being about 1912.

Q. What is meant by automatically advanced ignition, and how is this accomplished?

A. Instead of relying upon a manually operated spark lever under the steering wheel, a centrifugally operated device is incorporated with the timer or distributor. As this depends upon the speed of the motor for its operation, the ignition timing is always at the point of extreme retard when the motor is stopped, so that it may be cranked by hand without taking any precautions to retard the spark. The device is practically a small centrifugal governor the weights of which expand against the action of a spring under the influence of increasing speed. These weights are connected by a lever to the timer, or distributor housing, so that, as they expand

with increasing speed, they move the housing in the proper direction to advance the time of ignition. The spring automatically returns the housing to the retarded position when the motor slows down or stops. The automatic-advance device is a feature of the Atwater Kent battery system, and is also employed on one of the types of Eisemann magnetos particularly designed for use on commercial vehicles. It relieves the driver of the necessity of giving any attention to this part of the control, as the time of ignition is always proportioned exactly to the speed.

Q. When all other factors are fully up to requirements, such as proper carburetion, valves recently ground, spark-plug points not too far apart, and property fitting pistons, but the motor fails to operate with the same "snap" and power it delivered when newer, what is likely to be the cause?

A. Wear in the linkage connecting the spark-advance lever with the timer, the breaker box of the magneto, or the distributor of a modern battery system, is responsible for so much lost motion that the full movement of the spark-advance lever is no longer being transmitted to the ignition apparatus. In other words, the full advance of the spark lever on the steering wheel no longer represents the maximum advance at the timer or distributor, so that the motor is not firing as early as it should and a considerable percentage of the energy, represented by exploding a fully compressed charge, is being wasted. The effect is the same as loss of compression from any other cause.

Q. When the motor will run slowly at one moment and then speed up to the racing point without any apparent cause, then drop off again to slow speed, what is likely to be the cause?

A. Unless this is directly traceable to a partially clogged carburetor jet or a loose throttle which is jogged open and closed by the vibration, the wear mentioned above may be responsible. The spark-advance linkage has become so loose through wear that it no longer holds the timer or distributor at the point to which the lever is moved on the quadrant on the steering wheel, and the vibration of the motor moves it back and forth, advancing it at one moment and retarding it the next.

Q. When the motor does not respond at all to the movement of the spark-advance lever, what is the trouble?

A. There is an actual break between the lever on the steering wheel and the timer, or distributor, or the breaker box of the magneto. This is apt to leave the ignition timing fully advanced, making it dangerous to attempt to start the motor by cranking it on the battery.

Q. Why do some motors require a greater amount of ignition advance than others?

A. Because of their greater speed or the increased amount of lag in the ignition system which must be compensated for by the timing.

Q. What system of ignition has the greatest amount of lag, and which the least?

A. The old battery system, using a roller-contact timer and vibration coils, has the maximum amount of lag, as there is both a mechanical and an electrical lag. The high-tension magneto and the modern battery system are great improvements in this respect, and there is not much choice between them on this point. As an illustration of the effect of the motor speed on the amount of advance required, the Packard "twin-six", using a modern battery system, requires as much advance as the old Packard "four", on which a low-tension magneto was employed; while the Packard six-cylinder motor, which was fitted with a high-tension magneto, required considerably less than either of these.

Q. Why is it necessary in some ignition systems to set the spark "late", or after the piston has actually started downward on the firing stroke, when the spark lever is at the point of maximum retard, while in others it is only necessary to set it at upper dead center?

A. This is due to the difference in the amount of lag, and also to whether a battery or a magneto is employed. It is necessary to insure safety in hand cranking, as, where the lag is reduced to the minimum, the explosion would take place before the piston had reached a point where it could start downward on the firing stroke, and a back kick would result.

Q. Is the piston actually at upper dead center for ignition-setting purposes when it has ceased to rise?

A. No. There is an interval in the revolution of the crank during which the piston does not move, i.e., while the crank is moving

in practically a horizontal plane, and it should complete this part of the revolution, so that the piston is just on the point of starting downward again before it reaches the proper point for ignition setting at maximum retard.

Q. What is meant by "fixed" ignition?

A. This refers to those systems in which there is no provision made for altering the time of ignition, either by a manually operated lever on the steering wheel, or by an automatic device for advancing and retarding it. In other words, the time of ignition is fixed and is always the same, regardless of the speed of the motor. It can be used only in connection with a magneto.

Q. What is the ignition-setting point for "fixed" spark?

A. This represents a mean between what would be the points of maximum retard and maximum advance in a variable system. The spark must not occur too late as the motor will develop only a percentage of its power and will overheat; nor must it be too early, as the motor is then apt to fire against the rising pistons when slowed down, as in climbing a hill or when heavily loaded. The magneto must be set, therefore, so that the spark occurs before the piston reaches upper dead center. Just how much in advance of that point the setting should be, will depend upon the motor itself. As will be noted in the table of firing orders, a much greater range of timing is allowed for on some motors than on others, so that there is no rule which will apply to all. The ignition-setting point as given by the manufacturer should be learned and the magneto set in accordance.

Q. Is fixed spark ignition in common use on American cars?

A. Although very largely used abroad, particularly in France, on commercial vehicles such as taxicabs, it has never found favor here and will be found on very few cars.

Q. Is there any other method of checking the ignition-setting point besides the marks on the flywheel or the position of the piston of one cylinder in its relation to the contacts of the interrupter?

A. In some magnetos, such as the Eisemann, there is a setting mark on the distributor of the magneto. When the piston is in the proper position for firing, it is only necessary to bring this setting mark in line with a setting screw on the stationary part of the distributor.

Q. Why do the cylinders of an automobile engine not fire consecutively?

A. Because the pistons are attached to the crankshaft in pairs in the same plane, so that when one piston of a pair is firing the other one is going down on the exhaust stroke.

Q. How can the firing order of a motor be determined?

A. Take out all the plugs and lay them on the cylinders so that the threaded part of the plug makes contact with the cylinder but the terminal does not. Switch battery on and turn engine over slowly, noting the order in which the sparks occur at the plugs. Watch the valve stems; after the inlet valve of cylinder No. 1 has opened and closed, it is ready to fire. The plug at which the spark then occurs is the proper plug for the first cylinder. The next plug to spark belongs to the cylinder whose inlet valve has just closed.

Q. When a motor will not start, but fires once or twice and then stops, the flywheel rocking back and forth, what is the cause?

A. Some of the spark-plug leads have been misplaced, so that after one or two explosions, the next one takes place out of sequence.

Q. How many different firing orders are possible in a motor?

A. This depends upon the number of pairs of cylinders in a motor, as the two cylinders of a pair cannot fire consecutively, so that the ignition alternates from one pair to another. For example, in a four-cylinder motor, cylinders No. 1 and No. 4 constitute one pair, in that they are attached to crankpins in the same plane, i.e., they rise and fall together; cylinders No. 2 and No. 3 constitute the other pair. Consequently, starting with cylinder No. 1, there are only two firing orders possible in a four-cylinder motor, as follows: 1-2-4-3, or 1-3-4-2. By starting with cylinder No. 2, as the first to fire, two more orders may be used, as 2-1-4-3 or 2-4-3-1. It will be apparent, of course, that the last-named combination is merely the reverse of the second one given above, i.e., 1-3-4-2. In this way, the total number possible with a motor of this type is eight firing orders.

Q. Do motors differ much in this respect, or are firing orders pretty well standardized?

A. Of the eight possible firing orders that may be used in a four-cylinder motor, only two are in common use, viz: 1-2-4-3, and 1-3-4-2. This is because the selection of cylinder No. 1 as

the first to fire renders it easier to set the ignition timing, as the piston of the first cylinder is usually more accessible than the others. There are some exceptions to this, the 2-1-4-3 firing order having been used by one or two makes of cars for several years; but the two mentioned above are in such general use as to be considered practically standard.

Q. How does the firing order of a six-cylinder motor differ from that of a four?

A. It is exactly the same in principle, as the six consists of three pairs of cylinders, the pistons of which are attached in couples to the crankshaft, 120 degrees apart; in other words, a three-throw crankshaft, instead of the *two-throw* of the four-cylinder motor, in which the cranks are 180 degrees apart. *Pairs of cylinders,* in this connection, has no reference to the manner in which they are cast, but refers simply to their relation to the crankshaft, which, in turn, affects their firing order. The ignition must accordingly alternate from one pair to another in exactly the same manner as in the four, but a greater number of combinations is possible as there are three pairs of cylinders.

Q. What are some typical firing orders for six-cylinder motors?

A. As in the case of the four-cylinder motor, the use of cylinder No. 1 as the starting point has been practically standardized, hence the firing orders in general use begin with it, as: 1-5-3-6-2-4, or 1-4-2-6-3-5.

Q. How does the firing order of an eight-cylinder motor differ from that of a four?

A. In view of the fact that the usual V-type eight-cylinder motor is nothing more nor less than two four-cylinder motors working on the same crankshaft, or, as it may be better put, with a common crankshaft, the firing order is simply that of two four-cylinder motors in which the ignition alternates from one motor to the other. That is, in addition to alternating from one pair of cylinders to the other, as already described, the firing also must alternate from one group of cylinders to the other, so as to maintain the impulse balance of the motor. The explosion in a right-hand cylinder must always be followed by the firing of a left-hand cylinder.

Q. What are the usual firing orders of eight-cylinder motors?

A. The same as those for fours, i.e., 1-2-4-3 and 1-3-4-2,

alternating from one group of four cylinders to the other, as, for example, L1-R3-L2-R1-L4-R2-L3-R4, or R1-L4-R3-L2-R4-L1-R2-L3. The number of combinations is increased as the firing order may start with the first right or the first left cylinder.

Q. How does the firing order of the twelve-cylinder motor differ from that of the six?

A. It bears the same relation to the six that the eight does to the four. In other words, the twelve-cylinder motor is practically two six-cylinder motors, or two groups of six pistons each, working on a common crankshaft.

Q. Give the firing orders of two of the twelve-cylinder motors now in use?

A. The Packard twin-six firing order is R1-L6-R4-L3-R2-L5-R6-L1-R3-L4-R5-L2. That of the National twelve is R1-L6-R5-L2-R3-L4-R6-L1-R2-L5-R4-L3.

Q. What is the effect of a cylinder firing out of order?

A. The spark may either occur when there is no gas in the combustion chamber, in which case that cylinder will miss when it should fire, or it may take place in a cylinder that will be fired so as to act *against* the other cylinders instead of *with* them. In either case, irregular running will result. Where there are either eight or twelve cylinders, the fact that one is either missing or firing against the others will not stop the operation of the motor; the misfiring of a single cylinder in a twelve is scarcely perceptible, except at low speeds. But in a four or six, the misplacing of a pair of spark-plug leads will prevent the running of the motor altogether.

Q. Is it possible to have one cylinder fire out of order?

A. It will be evident that, as the cylinders in all automobile motors fire in alternate pairs, the misplacing of one spark-plug lead naturally involves the dislocation of its mate or its alternate. Consequently, one cylinder cannot fire out of order alone; two will always be affected. For example, in a four-cylinder motor, if the secondary cable to the plug of cylinder No. 1 is connected to the spark plug of cylinder No. 2, it is apparent that No. 2 also must be misplaced. Granted that there is no other fault in this respect, it will be found connected to the plug of No. 1.

Q. Give a typical example of misplaced spark-plug leads causing improper firing order and its consequences?

A. Take the instance cited above. Cable No. 1 has been connected to cylinder No. 2; cable No. 2 has been connected to cylinder No. 1. The firing order is 1-2-4-3, which means that when the piston of cylinder No. 1 is going down on the power stroke, the piston of cylinder No. 2 is drawing in a fresh charge of fuel mixture through the open inlet valve. But, as cable No. 2 is connected to cylinder No. 1, no spark takes place when the piston finishes its upward travel on the compression stroke, and no explosion results. The spark instead of occurring in cylinder No. 1, takes place in cylinder No. 2, and may ignite the incoming gas, resulting in a weak explosion or a back-fire through the inlet valve. If the placing of the inlet valve be such that the incoming charge is not fired by the spark of cylinder No. 1, but takes place in cylinder No. 2, on the suction stroke, nothing will occur in cylinder No. 2, either. When its piston comes up on the compression stroke ready for firing, the spark occurs in cylinder No. 1, and the fresh charge passes out of the exhaust valve of cylinder No. 2 without being fired. In other words, both cylinders No. 1 and No. 2 miss. Cylinders Nos. 3 and 4 being connected up in the proper order, however, they will fire as they should, but in a four-cylinder motor they are not sufficient to keep the motor turning over steadily. It will give two jerky explosions and stop. After cranking several times, cylinder No. 2 will become more or less filled with fresh gas, and a back-fire will result at every other revolution, or every time it is the turn of cylinder No. 2 to fire. Cylinder No. 1 is not likely to back-fire, since the spark is occurring in its combustion chamber on the exhaust stroke.

Q. What would be the effect if, instead of connecting to cylinder No. 1, the lead of cylinder No. 2 misconnected to No. 3?

A. As the firing order of the motor is 1-2-4-3, it will be evident (the other cables being correctly connected) that cylinder No. 1 will fire properly; No. 2 will miss; No. 4 will fire properly; and No. 3 will either miss or back-fire; so that the motor as a whole will run very jerkily; although it will continue to run on this combination, i.e., one operating cylinder in each alternate pair firing a revolution apart. In this case, when the piston of cylinder No. 2 has just finished compressing its charge and should fire it, its spark takes place in the combustion chamber of cylinder No. 3, which is then exhausting, so that it is also much more likely to miss than to back-

fire. The effect will be practically the same as if no spark at all took place in either of these two cylinders, and the motor will run on one pair alone.

Q. Is it any more difficult to locate trouble due to the cables being connected in the wrong firing order, in motors having six, eight, and twelve cylinders?

A. The greater number of cylinders would naturally add to the confusion, and the fact that it is not easy to tell off-hand when one cylinder in an eight or twelve is missing, contributes to the difficulty of locating the one at fault. On the other hand, however, the spark-plug leads are so designed that it is much more difficult to connect them up in any but the right way, as they are cut to exactly the proper length and are usually numbered in addition. The contacts of the distributor are also identified in the same manner, so that the connections may be readily checked without making tests of any kind; it is only necessary to trace the cables from the distributor to the plugs. The fact that the motor will continue to run on a pair of cylinders, even though its leads should be misplaced, is misleading, as the missing, or faulty running, is likely to be ascribed to a poor spark plug or something of that nature rather than to the real cause.

Q. Can the firing order of the cylinders be disarranged in any other way than by the misplacing of the secondary cables connecting the distributor to the spark plugs?

A. No. Since the timer, in the case of a timer- and four-vibrator-coil ignition system, as on the Ford, or the distributor, as on a magneto or battery-ignition system, makes its contacts consecutively. That is, on a four-cylinder timer or distributor, the contacts occur in the order 1-2-3-4 and, unless the leads are properly connected up, the sparks will occur in the cylinders in the same order. To obtain the firing order mentioned in a previous query for a four-cylinder motor, i.e., 1-2-4-3, contact No. 1 of the distributor is connected to cylinder No. 1, contact No. 2 to cylinder No. 2, contact No. 3 to cylinder No. 4, and contact No. 4 to cylinder No. 3. The connections would naturally be the same in the case of a timer, as there is then an independent induction coil for each cylinder of the motor.

Q. Has grounding or short-circuiting of the secondary leads any effect on the firing order of the motor?

A. This may be the case where two secondary cables touch

each other and there is a short-circuit at the point of contact. For example, assume that the cables of cylinders No. 1 and No. 2 cross each other in running from the distributor to their respective spark plugs (this is poor practice in wiring, but it is nothing unusual to see it on old cars) and that there is a leak in their insulation at this point. After being in service for some time, spark-plug points burn away unevenly, so that the gap at one is less than at the other. Consequently, there will be less resistance at this plug than at the one with the wider gap; in short, the combined resistance of the leakage gap where the cables cross and that of the spark plug with the smaller opening may be less than that of the plug which has burned further apart. Then the current intended to produce a spark at this plug will leak through the insulation and produce a spark at the other plug instead, and the latter will fire out of order while the first plug will miss.

Q. Does a change in the firing order of a motor have any effect on its running? For example, assume a four-cylinder motor designed to run with the firing order of 1-2-4-3. Will such a motor run any better if the firing order be shifted to 1-3-4-2, or to 2-1-3-4? Can this be done easily?

A. So far as the actual operation of the motor is concerned, such a change would have no particular effect, as a cylinder of each alternate pair would fire consecutively. The change can be made without any difficulty, on the average motor, by providing new secondary cables, as the latter are usually cut to about the right length to reach from the distributor to the spark plugs in the firing order for which the motor is originally designed. The distributor would then have to be connected to the plugs in the following way: distributor contact No. 1 to cylinder No. 2, contact No. 2 to cylinder No. 1, contact No. 3 to cylinder No. 3, and contact No. 4 to cylinder No. 4.

Q. Why do different manufacturers adopt different firing orders, if there is no particular benefit to be derived from one as compared with another?

A. Chiefly to adapt the wiring more conveniently to the location of other essentials, such as the magneto or the distributor of a battery system, although the intake manifold design may influence the choice.

SPARK PLUGS

Q. What are the usual causes of failure of the spark plug?

A. An accumulation of carbon on the inner end of the porcelain and the shell, causing a short-circuit; broken porcelain; points burned too far apart to permit spark to pass.

Q. When there is a hissing noise at the plug, or when oil squirted on it bubbles violently with the motor running, what does it indicate?

A. Either that the porcelain of the plug is not screwed down tightly on its gasket on the shell, the porcelain is broken, or the plug itself is not tight in the cylinder.

Q. What is the cause of a discharge across the porcelain of the plug?

A. The points are too far apart, or the porcelain is broken; usually the former. This usually will be noted only on plugs having very short porcelains as where the latter are long, the distance is much greater than the maximum to which the points can be separated and any spark that would occur owing to the latter cause would take place at the safety gap.

Q. Why is it that when a good spark will occur between the points of a plug in the open air, an equally good spark cannot be obtained in the cylinder with the same distance between the points of the plug?

A. Compressing air increases its resistance to the electric current, so that a stronger current is necessary to produce the same spark under compression in the cylinder, as may be obtained in the open air with less current. This is one of the symptoms of a weak starting battery (dry cells). All the plugs will spark satisfactorily when removed from the cylinders, but it is found very difficult to start the engine by cranking. When fresh cells cannot be had, it may be overcome temporarily by adjusting the points of the plugs closer together, in this way obtaining a satisfactory spark with less current.

Q. What is the proper distance between the points of the spark plugs?

A. For good working with a magneto, this should not exceed $\frac{1}{32}$ inch. With storage-battery ignition, it may be greater, but it is good practice to employ the smaller gap with either.

Q. How rapidly do the electrodes of the spark plugs burn away, and what effect does this have?

A. This will depend upon the plugs themselves and the character of the current supply. The cheaper plugs with ordinary iron-wire electrodes will burn away very rapidly, becoming much too widely separated in a few weeks' use. With better grade plugs, using a hard alloy for the electrodes, the time will depend more or less on the magneto, or where a storage battery is employed, on the coil. Some produce a very much hotter spark than others and, consequently, burn the plugs away that much sooner; but a good plug ought not to need adjustment under two or three months of ordinary running. The fact that the plug points have burned too far apart will be evidenced by a very perceptible falling off in the power; by missing spasmodically in different cylinders at low speeds; and by an occasional discharge across the porcelain on the outside of the plug, if the latter is of the short type.

Q. What can be done when there is an escape of compression around the porcelain of the plug?

A. If the porcelain is not broken, this can be remedied by turning down the gland or packing nut which holds the porcelain in the metal shell. There is an asbestos washer under this packing nut, and tightening the latter causes it to fill completely any space between the porcelain and the shell. The nut should be given only a fraction of a turn, and the tightening should be done when the plug is cold; if it is tightened when very hot, the contraction due to the cold is liable to crack the porcelain.

Q. What is one of the commonest ways of breaking spark-plug porcelains?

A. The use of a big wrench in putting the plugs into the cylinders. Only a spark-plug wrench or a small wrench having but a 3-inch or a 4-inch handle should be employed. The leverage available with the big wrench is so great that the porcelain is crushed, frequently without the knowledge of the man using it.

Q. How can a broken porcelain be detected?

A. Usually by grasping the plug between the fingers and trying to turn the porcelain sideways or to revolve it. Any play is generally an indication that the porcelain is broken, though sometimes they will loosen up so much under the influence of vibration

that they may be turned easily with the fingers. Tightening the packing nut will overcome this. Where this treatment does not locate a break, squirting a little oil on the porcelain while the motor is running will do so.

Q. How long should a good plug stay in service?

A. This is hard to average, but with occasional adjustment of the points, a good plug will frequently continue to give satisfactory service for several thousand miles; some have been known to run for well over 10,000 miles, and still continue to operate satisfactorily. When the motor does not run properly and the plugs are suspected, it is better to try the effect of a new set and note the running of the motor carefully, before discarding the old ones, as the fault will frequently be found elsewhere. The first thing that many repair men do with a motor that is a bit off is to throw away a perfectly good set of spark plugs.

Q. What is a "series"-type plug, and what advantages has it?

A. This is a type of plug fitted with two insulated terminals, instead of one, as in the ordinary type, as it does not make a ground connection on the motor by being screwed into the cylinder. It is intended to be used in series with an ordinary plug, hence the name. The current passes through the series plug first, and then, through the second plug of the ordinary type, to the ground, thus producing two sparks instead of one. The advantages claimed for its use are a more rapid and thorough combustion of the mixture, due to the spark occuring at two widely separated places in the combustion chamber; but, in actual practice, the gain is not sufficient to warrant the extra complication, so that this type of plug is seldom used.

Q. What is the object of fitting a plug with several sparking terminals, or electrodes?

A. The current will always follow the path of least resistance and will accordingly bridge the smallest gap. The sparking will start at this gap and, when that particular electrode burns away, will shift to one of the others until that has also burned too far open, i.e., until its resistance becomes greater than that of the next one, and so on. Such a plug should stay in service longer without the necessity of adjusting the gap, but, apart from this, it has no particular advantage, as the short-circuiting of one of the gaps renders all of them useless.

Q. What threads are generally used on spark plugs, and which thread is to be preferred, from the repair man's point of view?

A. Half-inch iron pipe, metric and S.A.E. standard. Plugs with iron-pipe threads are employed only on the cheaper cars; metric-threaded plugs will be found on foreign cars only, and S.A.E. standard plugs ($\frac{7}{8}$ inch-18) on most, if not all, of the better American cars dating from about 1913 on. All work equally well so far as holding compression is concerned. The iron-pipe plug is likely to cause trouble in this way sooner than the others, as they do not depend upon the thread itself to prevent leakage. The S.A.E. standard plug is preferable, being a better mechanical product than the iron-pipe plug as the threads of the latter are not so accurate, and the plug itself is usually not so well made.

Q. When a spark plug leaks at the base, i.e., at the point where it is screwed into the cylinder, what is the cause?

A. If of the iron-pipe type which depends entirely upon its tapered thread to hold the compression, a section of the thread may have been damaged in handling. With either of the other types, the plug may not be seated snugly enough on its gasket, in which case a quarter-turn in will usually remedy the leak. If it does not, the gasket should be replaced with a new one.

Q. Is there any danger of turning an iron-pipe plug in too tightly?

A. If screwed home too tightly while the motor is hot, the plug may bind and become very difficult to remove, sometimes necessitating drilling it out and re-tapping the hole.

Q. Is the priming type of plug of any particular advantage?

A. On low-priced cars not fitted with pet cocks in the cylinders, it is an aid to starting in cold weather; though, as a matter of fact, the priming inlet of the plug is likely to become clogged with soot, so that it cannot be used for injecting gasoline into the cylinders.

Q. Why has the magnetic type of spark plug not come into general use?

A. It is an expensive type of plug to make and is more subject to derangement than the ordinary kind. It is only intended to be used with a low-tension magneto and plain-spark coil (single winding on an iron core), and this type of magneto has long since become obsolete on the automobile.

Q. Is porcelain or mica preferable, as the insulator of the plug?

A. While mica is practically unbreakable, it is liable to become saturated with oil and dirt, causing leaks that are hard to trace; so that the use of porcelain is preferable, despite its liability to breakage.

Q. Is changing from one make of plug to another likely to cause any difference in the running of a motor?

A. As the power of the motor is dependent, to a very large extent, upon the proper ignition of the charge, a change from one make of plug to another will sometimes make a very marked difference. Because of the great amount of variation in the width of the cooling jacket and the thickness of the cylinder walls, certain types of plugs are particularly adapted to certain makes of motors. In fact, the plugs have been designed especially for service on those motors. For example, some motors require an unusually long plug to permit of the sparking points extending well into the combustion chamber. In others, a plug of this type might interfere with the piston when at upper dead center. Always use the type of plug recommended by the manufacturer of the car.

Q. What is the cause of the spark plugs in a motor becoming fouled very rapidly?

A. An excess of lubricating oil is finding its way into the combustion chamber, and its burning there deposits a heavy layer of carbon on the ends of the plugs. This may be due to leaky piston rings; the use of improper oil for the motor, as where a very light oil, instead of a heavy bodied lubricant is used in a motor intended for the latter; or, in old cars, the lack of baffle plates between the crankcase and cylinders. Running the motor with an over-rich fuel mixture will also cause sooting of the plugs. The use of a heavier oil and with it a certain proportion of flake graphite, or "Gredag", will often greatly improve the compression of an old motor and effectively remedy this trouble.

Q. Is it advisable to use lubricating oil mixed with graphite in all old cars?

A. It is usually good practice, except on the Ford, as the magneto of the latter runs in oil splashed back from the crankcase, and the presence of graphite in this oil would short-circuit the magneto. In case this has been done on a Ford, it would be necessary to wash

the magneto out very thoroughly with gasoline to remove all traces of the graphite, and even that might not remedy the short-circuiting.

Q. When the plug in only one cylinder of a motor continually soots up very rapidly, what is the cause?

A. That particular cylinder is being flooded with oil, and an excess amount of it is reaching the combustion chamber. A piston ring may have broken in that cylinder, the rings may have worked around until their openings are in line with one another, or the supply system may have become deranged, causing an excess of oil to reach the section of the crankcase directly under that cylinder.

Q. Is there any way of knowing to a certainty before undertaking an inspection, whether missing is due to a faulty plug or to some derangement of the carburetor?

A. If the miss continually occurs in the same cylinder, it may be put down as due to the plug or wiring of that particular cylinder, even though the plug, when tested from the outside (i.e., without removing it from the cylinder), is apparently working properly. When the missing is spasmodic, occurring first at one cylinder and then at another, it is more likely to be due to faulty carburetor adjustment or a partially clogged carburetor nozzle. A weak dry battery, however, will produce similar symptoms; failing fuel supply also will, though, in this case, the whole motor will run jerkily one moment, speed up the next, and then almost stop, only to repeat the performance.

Q. Is the usual test, made by unclipping the secondary cable from the plug and holding it near the terminal with the motor running, always conclusive as to the proper working of the plug, when a spark occurs between the two?

A. No. Since a short-circuited plug will not prevent a spark from passing between its outer terminal and the end of the cable held near it. The gap made by disconnecting the secondary cable and holding it a short distance away has simply taken the place of the gap which should exist between the plug points. This test is conclusive only as to the proper functioning of the distributor and the integrity of the wiring connecting that particular plug.

Q. When the motor misses spasmodically, and there are intermittent discharges of high-tension current at different points on the cylinders, while it is running, what is the cause?

A. Moisture. The secondary cables have become wet enough to cause leakage of the high-tension current; usually the result of the careless use of the hose in washing. The only remedy is to run the motor continuously until the heat dries things out thoroughly.

Q. When no spark plug is obtainable at any of the plugs, so that the motor cannot be started, in what order should the cause of the trouble be run down?

A. If a dry battery is used as the source of current, first see that it is not exhausted by testing with a small ammeter. Each cell should show 10 amperes or more. If one is considerably below the others, it reduces them to its level. Where a storage battery is used, switch on the lights as a test. They should burn brightly. Provided there is no failure of the current, inspect the interrupter, or contact breaker; see that its points separate when the high part of the cam strikes the arm carrying the movable point. If they do not separate, no current is induced in the secondary winding, and an adjustment of the points, to open about the space represented by an ordinary visiting card, will remedy the trouble. If the points open properly, inspect the wiring and connections between the interrupter and the battery. Should both the interrupter and its wiring be O. K., note whether the ground connection from the coil is fast. Failing all of these, inspect the high-tension distributor. This is about the order in which the trouble would be likely to occur.

Q. When the motor continues to run after the current has been turned off, what is the cause?

A. The cylinders have become so hot, due either to lack of oil or or low water in the cooling system, failure of circulation, etc., that either the spark-plug electrodes have become red hot, or particles of carbon, deposited in the combustion chamber, have become incandescent, thus firing the charge. The fuel supply must be shut off and the motor allowed to cool.

Q. Should the motor back=fire when attempting to start, even though the spark=advance lever has been pulled back as far as it will go, what is causing the trouble?

A. The linkage connecting the spark-advance lever with the breaker box of the magneto or of the interrupter (battery system) has parted at some point, so that it no longer moves the breaker box to retard the time of ignition.

REGULATION DEVICES

Interrupters and Timers

Q. How does an interrupter operate?

A. It is normally closed, short-circuiting the battery on the primary winding of the coil until just before it is necessary for the spark to occur in the cylinder; a cam then separates the contact points, and the high-tension current induced in the secondary winding of the coil jumps the gap of the plug. In the case of a magneto, the winding of the armature is short-circuited on itself to permit it to "build up", so that when the interrupter contacts are opened by the cam, the peak or highest value of the current wave generated is utilized. The opening of the circuit in either case occurs at the same time the distributor arm is passing one of its contacts.

Q. How does a timer operate?

A. Contacts, insulated from each other, their number corresponding to the number of cylinders, are located at equidistant points on the inner circumference of the timer housing, while the shaft carries a single contact which in its revolution successively touches each one of the stationary contacts. Where separate vibrator coils are used, as on the Ford, each stationary contact corresponds to one of the coils.

Q. Do interrupters and timers fail from the same causes, and what are they?

A. No. The cause of failure in one case is the reverse of that in the other. An interrupter fails when it does not open the circuit, and a timer when it does not close it. Dirt and wear are the usual causes of failure in both cases; moisture is also responsible at times. Test by having an assistant turn the engine over slowly by hand and watch the operation of the interrupter; if the cam fails to separate the contact points, true up their faces with fine sandpaper and test again. (This does not apply to Atwater Kent interrupters. See description.) Stop with the cam in the opening position and see if a sheet of ordinary paper can be slipped between the contacts. See that there is not an excess of oil in the housing, as oil on the contact point insulates them. In the case of a timer, see that the spring of the movable contact has sufficient tension to keep it pressed firmly against the stationary contacts as it revolves; note whether sufficient wear has occurred to cause poor contact even with sufficient spring pressure.

Q. How far should the contacts of an interrupter separate?

A. This differs somewhat with different systems, but in the case of the interrupters used on battery systems, it is very small, seldom exceeding a few thousandths of an inch. In the case of the Atwater Kent interrupter, this is .010 to .012 inch. (Coated catalogue paper is .005 to .007 inch thick; a thin visiting card is .010 to .015 inch thick.)

Q. How does the Atwater Kent interrupter differ from other battery interrupters?

A. The circuit is normally open and only remains closed momentarily before being opened by the dropping of the lifter into its notch on the shaft.

Q. Can this interrupter be tested in the same way as that just described?

A. No. The movement of the lifter in striking the latch to close the circuit is so rapid that it cannot be detected with the unaided eye, even though the engine be turned over very slowly by hand.

Q. What will cause this interrupter to fail?

A. Wear of the lifter to an extent where it will not engage the notches of the shaft properly, usually caused by lack of oil. Other causes of failure are the same as for other types, generally worn or burned contact points.

Q. When the contact points of an interrupter of any type burn away very rapidly, what is the cause?

A. The condenser has broken down so that it is no longer protecting the points from the full heating effect of the arc formed at the time of breaking the circuit. Use the testing-lamp outfit described in connection with lighting and starting systems. Apply one point to each of the condenser terminals; if the lamp lights, the condenser is short-circuited. The only practical remedy is replacement by the manufacturer, as even the best equipped garage is seldom fitted to take care of such work.

Q. Does discoloration always indicate burned contact points, and how often should these points require cleaning and adjustment?

A. No. According to the particular alloy used in the contacts they will assume a bright purple, an orange, or a gray tinge. The squareness of their surfaces and the contact they make when together are the best indications of whether attention is needed; if pitted or

high on one side, truing up will be necessary. Unless the condenser has failed, they should not require attention oftener than once a season, or say 6000 to 8000 thousand miles' running.

Distributors

Q. What is the function of the distributor and how does it differ from that of the interrupter and timer?

A. At the same moment that the interrupter opens the primary circuit of the coil, or the timer makes it in the case of a vibrating coil, the distributor makes contact with a stationary segment representing a spark-plug terminal. The distributor accordingly is said to run synchronously with the interrupter or timer. It is practically a duplicate of the timer designed to handle a high-tension current, in that it has one revolving contact and a stationary contact for each cylinder.

Q. Does the moving member of a distributor actually make contact with the stationary contacts, as in the timer?

A. No. This is not necessary owing to the high voltage of the current. The moving member passes very close to the face of the stationary contact but does not actually touch it, thus avoiding wear. This applies, however, only to those early-type magnetos or to separate distributors employing a metal moving contact. Where carbon brushes are employed, they are pressed against a fiber disc with a metal segment countersunk flush with its face and this segment passes under each carbon brush in rotation.

Q. What are the usual causes of failure in a distributor?

A. Short-circuits, due to moisture, dirt, or carbon dust. Owing to the high voltage of the current it will leak across barely perceptible paths caused by dampness or carbon dust.

Q. What is the so-called ignition unit of the modern battery system?

A. This is a combined contact breaker and distributor similar to the contact breaker and distributor of a magneto—in other words, a magneto minus the current-generating end. It is mounted on a vertical shaft and is driven through bevel, or helical gearing, from either the camshaft or one of the auxiliary shafts of the engine (i.e., water pump or magneto-drive shaft). The contact breaker is placed directly below the distributor, the secondary cables coming out of the upper face of the latter. (See description of Westinghouse and Connecticut units.)

Q. What is the "unisparker"?

A. This is the Atwater Kent ignition unit and is similar in general design to those referred to above but it is an "open-circuit" type, while they are "closed-circuit". The term is a trade name derived from the fact that the contact breaker makes but a single spark, as compared with the vibrator coil which produces a series of sparks only one of which, however, is available for ignition. All contact breakers on magnetos and, as now used, on modern battery systems, produce but a single spark. The time of ignition is so limited on a high-speed engine, that, if this single spark fails to ignite the charge in the cylinder, subsequent sparks are of little value, as the piston is already well down on the firing stroke by the time a later spark occurs, and much of the force of the explosion is lost.

Q. How is the time of ignition advanced and retarded on the ignition unit?

A. Usually by altering the relation of the moving contact of the distributor to the stationary contacts. The distributor plate, i.e., the insulating disc carrying the stationary contacts is connected to the spark-advance lever on the steering column, and it may be moved part of a revolution backward or forward to advance or retard the time of ignition. To alter the timing, the position of the moving contact on its driving shaft may be shifted. For example, in the Delco distributor a central screw in this member is loosened, and the contact may then be moved in either direction with relation to the shaft.

Switches

Q. What is a "reversing" switch and why is it employed on ignition systems?

A. It is a double-contact switch which reverses the polarity of the current, i.e., its direction, through the contacts of the interrupter every time the switch is closed. This is done to prevent the burning away of the contact points in one direction which would cause a peak to form on the positive and a crater, or depression, on the negative. Reversing the direction of the current causes the points to become alternately negative and positive in accordance with the position of the switch.

Q. What is the nature of the trouble ordinarily to be looked for in a switch?

A. Poor contact due to wear or weakening of the spring; broken or frayed connections causing a ground or short-circuit.

Q. What is an automatic switch?

A. This term is frequently applied to the battery cut-out of the lighting and starting system. On the Connecticut ignition system, it is a thermally operated switch, designed to open the circuit when the switch has inadvertently been left on after the engine has stopped.

Q. Are there any troubles peculiar to automatic type of switch?

A. None that is not equally so of any similar device such as the battery cut-out or the circuit breaker.

Coils

Q. How many different types of coils are employed in connection with ignition systems?

A. Three. The first and simplest of these is usually termed a *spark coil,* and consists of a single winding of coarse wire on a heavy iron wire core. It acts by self-induction, the circuit remaining closed long enough to permit the core to become thoroughly magnetized; the energy thus stored in the core being released when the circuit is broken again. This gives increased voltage at the spark plug and causes an "arc" rather than a spark at the latter when the terminals of the plug are separated. This type of coil is only employed in connection with low-tension or mechanically operated spark plugs, and this system is now used on stationary engines and motor boats exclusively, having long since become obsolete on the auotomobile.

The other two types are known as induction coils, and differ merely in one being fitted with a vibrator while the other does not require this attachment to operate it. The induction coil is a miniature step-up transformer. It consists of a core of iron wires on which the primary of two or three layers of No. 16 or No. 18 wire is wound almost the full length of the core, and a secondary of many thousand turns of very fine wire, such as No. 36 or 38 B. & S. gage, or even No. 40, which is almost as fine as a hair. In coils of the best construction, this fine wire is wound in pancakes, or narrow sections, several of which are necessary to complete the secondary. Their terminals are connected in series thus making practically a single winding. Heavy insulation is placed between the primary and secondary windings, and the containing case is usually filled with an insulating compound, melted into it and becoming solid when cold.

Q. Why is an induction coil termed a "step=up" transformer?

A. It literally steps up or raises the voltage of the current sent through it. The primary winding is connected to the source of current and the secondary to the spark plugs through the distributor.

Q. Is the action of the coil based on the same principle as that utilized in generators and motors?

A. The principle of induction, as explained in Part I, is the same in all three, though it is utilized in a different manner in the induction coil. Instead of a moving coil of wire cutting the lines of force of a magnet, impulses are produced either by sending a pulsating current through the primary winding or by using an alternating current.

Q. How is this pulsating current produced in the primary?

A. By placing a vibrator in series with the primary winding.

Q. Of what does the vibrator consist, and how does it act?

A. It consists of a spring-hinged armature and a pair of adjustable contact points, exactly as in an ordinary electric bell or buzzer. This armature is located directly over the end of the core of the coil and close to it. When a current passes through the primary winding, it makes the core strongly magnetic and attracts the armature. This pulls the latter away from the stationary contact point and breaks the circuit, so that the core is no longer magnetic. The spring immediately pulls the armature back and recloses the circuit, this action taking place at high speed as long as the current is on.

Q. Why is the vibrator not necessary when an alternating current is used?

A. The rise and fall of the current wave, from zero to maximum and back again in the reverse direction, produces the same effect of magnetizing and demagnetizing the core of the coil very rapidly.

Q. Is the vibrator coil as rapid in action as the induction coil used with alternating current?

A. No. Since there is a mechanical as well as an electric "lag", or delay. The inertia of the armature must be overcome before it can be pulled down by the core, and to do this on a vibrator adjusted to withstand road shocks, the core must become *saturated*, or strongly magnetic. The time necessary to overcome the inertia of the armature is the mechanical lag, while that required for the core to become saturated is the electrical lag. In combination they make the

vibrator coil very much slower in action than the other type, and this is greatly accentuated by a stiff adjustment of the vibrator spring.

Q. Why is a vibrator necessary with one type of battery ignition and not with another, i.e., the so-called modern battery ignition?

A. Owing to the type of timer or interrupter, frequently erroneously termed the "commutator", employed on the two systems.

Q. What is the difference between the old-style timer and the modern interrupter?

A. In the former, a long contact is provided for each cylinder and the revolving contact member is in touch with this for quite an appreciable period of time, during all of which the vibrator of a coil of that type is in action. If the contact member of the timer were depended upon to make and break the circuit through the coil to obtain the spark in the cylinder, the stationary contacts in the housing would have to be very much shorter, and no provision for advancing and retarding the time of ignition would be available. Furthermore, the wiping contact of the ordinary style of timer is not adaptable to the extremely rapid make-and-break that is necessary for this purpose. The interrupter of the modern battery system is designed along practically the same lines as the contact breaker used in the primary circuit of a high-tension magneto or the only circuit used on a low-tension magneto. Its parts are made very small and light and with great accuracy, so that its inertia is reduced to the minimum and it will act with extreme rapidity. The gap is so small and the rapidity of action so great that the movement is often not visible to the unaided eye. It is practically a mechanical vibrator designed to give a single make-and-break at exactly the right moment as compared with the electrical vibrator, which must be started well in advance of the moment ignition is required, and which continues in action after the spark has occurred in the cylinder. Consequently, both the mechanical and the electrical lag, which make the vibrator coil comparatively slow in action, are reduced to a minimum, and the amount of current necessary is cut to a fraction of that required by the latter.

Q. How can the speed of operation of a vibrator be judged?

A. By the note it produces in action. A low note well down the scale denotes slow action; the higher the note, or buzzing, the more rapid the vibrator is acting.

Q. What effect on the ignition has the speed with which the vibrator operates?

A. A slow-moving vibrator increases the amount of lag and retards the ignition accordingly. This causes a corresponding reduction in the power of the engine, as the spark does not occur at the proper time to give the best efficiency.

Q. What is a master vibrator?

A. The vibrator type of coil on a multi-cylinder engine requires an individual coil for each cylinder, and it is often found difficult to adjust all of the vibrators so that they will act uniformly. If some are stiffer than others they will not act so rapidly, and the time of explosion in the cylinders they control will be delayed, causing uneven running of the engine. To overcome this, an extra coil with a specially made vibrator is connected in series with the timer and the other coils, so that its vibrators acts for each coil in turn, the vibrators of the other coils either being removed or screwed down hard so that they cannot act. This makes but one vibrator to adjust, instead of the four on a four-cylinder engine. As it controls all of the other coils, it is known as a master vibrator.

Q. Is the vibrator type of coil still in general use?

A. It has long since become obsolete on all cars except the Ford.

Q. As the Ford magneto produces an alternating current, why are vibrator coils necessary?

A. The Ford magneto has sixteen poles, and the armature which serves as the flywheel, carries sixteen coils, so that the number of alternations at the high speed at which the Ford motor runs, is very great. These alternations, or cycles, are so rapid that they overlap each other, as is evidenced by the steady burning of the incandescent headlights. The induction coil does not act quickly enough to be affected by the change of polarity so that a vibrator is necessary on each coil to produce a sufficiently hot spark for ignition.

Q. How can the four vibrators of the Ford coil be adjusted so as to operate uniformly?

A. The fact that they are not doing so, will be evidenced by the uneven running of the motor. Determine, by holding down the vibrators, one after the other, which cylinder or cylinders are lagging behind the others in firing. This will cut out the cylinders in turn; in fact, two may be held down at once, and the action of the remaining

pair noted. When the cylinder, or cylinders, at fault have been determined, adjust one at a time by releasing the lock nut of the adjusting screw of the vibrator and turning it up or down, according to whether improvement in running is noted, or not. Usually only a small fraction of a turn one way or the other will be necessary. Turn the screw very slowly and very little at a time and, when the proper adjustment of the screw has been secured, lock in place again securely. Ordinarily, the proper adjustment may be secured simply by noting the running of the motor. When all the cylinders fire regularly and without any apparent lag, the adjustment is considered correct. To secure a finer adjustment, a small portable ammeter, reading by tenths to three or five amperes, may be used. Connect this in series with each one of the coils in turn, and note the reading at which the coil acts most rapidly. The other vibrators may then be adjusted to give the same reading. When dry batteries were relied upon for ignition, this test was employed to reduce the current consumption to the minimum but with the excess supply of current from the Ford magneto, this is not necessary, and the vibrators may be adjusted to the reading giving the most rapid action, regardless of the current consumption. This test may be employed also to check the operation of the magneto, as its current output may have fallen off to a point where it is no longer sufficient to operate the coils satisfactorily.

Q. Why is a vibrator not necessary on the alternating current generated by the ordinary type of magneto?

A. The latter has but two field poles and a single coil on a two-pole armature, so that its cycles are very much fewer in number, and there is definite drop in the current, from the maximum to an absolute zero, twice in every revolution. Assuming a speed of 1200 r.p.m., the ordinary magneto would be running 600 r.p.m., as it is driven by a half-time shaft of the motor. This is 10 revolutions per second times 2 cycles per revolution which gives an alternating current of but 20 cycles, or one which would cause an incandescent lamp to flicker very badly. The Ford magneto, on the other hand, is directly on the crankshaft. Consequently, it is turning 20 revolutions per second, and its coils produce 16 cycles per revolution, or 320 cycles per second, equivalent to 19,200 alternations per minute. For ordinary commercial lighting, only 60 cycles per second are necessary to produce a steady light. The drop to zero in the current curve of the ordinary

magneto permits the core of the coil to become demagnetized, and it is then remagnetized by the subsequent rise to the maximum value in the other direction, so that no vibrator is necessary to accomplish this alternate magnetizing and demagnetizing of the core which is needed to produce the inductive effect in the coil or transformer.

Q. How many connections are there on a coil?

A. Three; one to the primary, from the battery or magneto; one from the secondary, to the distributor, in the case of a single coil, or to the spark plug in the case of a multiple coil; and one to the ground. The last named is referred to as a common-ground connection, as it grounds one side of both the primary and secondary windings of the coil.

Q. How are these connections made?

A. On the single non-vibrator coil, as used with an ordinary magneto, by means of wire cables from the magneto to the primary of the coil, from the secondary of the latter to the high-tension distributor. In the case of the Ford multiple-vibrator coils, each coil is an independent unit, having brass strap connections attached to the bottom of the coil-unit case. These straps are of spring brass and they bear against corresponding plates of brass in the bottom of the coil box fastened to the dash. Simply lifting the coil unit out of the box breaks the connection and automatically remakes it when the coil is replaced. Due to this type of connection, irregular firing of the Ford motor will frequently be found to result from the cover of the coil box not being snapped down tightly. This permits the coil units to jump around in the box owing to the jolting and vibration, and every time they are jolted up off their connections, a cylinder fails to fire, as the coil does not receive any current. Coils used in connection with modern battery systems are often grounded in the same manner as the magneto, i.e., by their attachment to a plate on the motor the ground wires of the coil being connected to this plate.

Q. When a coil fails to operate, how can it be tested for faults?

A. In the case of the single coil, used in connection with an ordinary magneto, disconnect it and test with the testing-lamp outfit described in connection with lighting and starting systems. Place one of the terminals of the testing set on the common-ground connection, then place the other in turn on the primary and the secondary leads. If the windings are intact, the lamp should light each time.

Should it fail to do so, the covers of the coil may be removed to note if a wire has broken just beneath it. This is most likely to be the case with the secondary, owing to the very fine wire used. If there is no break, either at this point or where the primary lead is connected to its winding, it will be necessary to return the coil to the manufacturer as there is an internal short-circuit, which cannot be repaired in the garage. The only difference between the method above outlined for a single coil and that of a unit-vibrator coil as used on the Ford, is to touch the test points to the brass strap connections representing the different windings.

Q. Why is but one coil used in connection with an ordinary magneto, while four are employed on the Ford?

A. Where a single coil is used, the secondary current is led to a distributor from which it is again led to the various spark plugs in the proper order of firing. No distributor is employed on the Ford, so that a vibrator coil is necessary for each cylinder. The connections from the coils to the plugs are made in the same order as they would be to a distributor.

Q. When a vibrator coil cannot be made to function properly by adjusting the contact screw, what should be done?

A. The contacts should be trued up with a very fine file, as failure to function will usually be caused by their having become badly burned away or pitted, thus making poor electrical contact. Where the above is the case and the contact points are square and true, it is only necessary to clean them by drawing a worn piece of fine sandpaper between them several times, first on one side and then on the other. See that none of the holding screws of the vibrator frame have become loosened, and that the lock nut of the movable contact holds the latter firmly in place when tightened up.

IGNITION BATTERIES

Q. What types of batteries or cells are used for ignition?

A. Dry cells and storage cells, or accumulators. (For queries on the latter see under "Battery" in Lighting and Starting Section.)

Q. What type of cell is the so-called dry cell?

A. It is a primary cell, i.e., one in which a current of electricity is generated by chemical reaction, and is technically known as an "open-circuit" battery.

Q. Of what does the dry cell consist, and how much current does it generate?

A. The elements are the zinc container and a carbon plate centrally placed in the container and insulated from it at the bottom. Around this carbon plate, which constitutes the negative element (the negative element in a primary battery carries the positive terminal and *vice versa*), is packed a depolarizing agent, usually dioxide of manganese. The active solution is sal ammoniac in water which is poured in after the cell is assembled and filled with the depolarizer, and then the cell is sealed at the top with pitch, so that it is dry in name only. No chemical action can take place without the presence of moisture.

A dry cell of the ignition type generates a current of 20 to 25 amperes (when new) at a potential of $1\frac{1}{2}$ volts.

Q. Why is a depolarizing agent necessary?

A. The action of the cell generates hydrogen gas, which quickly covers the carbon plate in the form of globules, rendering it inactive. The cell is then said to be *polarized*, and the current generated drops off very rapidly. This may be illustrated by placing an ammeter across the terminals of a new cell. The ammeter reading will remain at 20 amperes for a short time and then will quickly drop until, at the end of five minutes, the instrument will show scarcely any reading at all. If the connection is broken and the cell allowed to stand for ten minutes, it will again show almost as high a reading as before; at the end of an hour or more of rest, it will give practically the same reading. The depolarizing agent has in the meantime absorbed the gas which prevented the action of the cell.

Q. Why is it termed an open-circuit cell?

A. Because it will only produce its normal output for very short periods and must be allowed to rest between each demand for current. Otherwise, it will quickly become polarized and, if tested in this condition, will apparently be dead. It cannot be used where a steady current is required but must normally stand on open circuit.

Q. How is the dry cell employed for ignition?

A. Four cells are connected in series to give current at 6 volts, and a battery of this type is ordinarily employed, either as an emergency stand-by or simply for starting purposes. Where an open-circuit type of interrupter is employed, such as the Atwater Kent, it

may be used as the main source of ignition current; as this interrupter makes instantaneous contact only at the moment the spark is required in the cylinder, the battery otherwise being on open circuit.

Q. How can the life of such a battery be prolonged?

A. By connecting two or more sets of four cells each in series-multiple, i.e., each group of four is connected in series to give the required voltage, and the positive and negative terminals of each group are connected together. The amount of current then drawn from each cell is only one-half what it would be if a single set of cells were employed, or one-third what it would be where sets are in series-multiple, and so on.

Q. When a set of four dry cells will last a certain length of time, why is it that adding extra cells in series, for example, a six-cell battery, will not last longer?

A. The amount of current drawn from the cells when the circuit is closed depends upon the voltage of the entire series, and the greater the total voltage the larger the volume of current, in accordance with Ohm's law. Consequently, the six-cell battery will not last so long as the four on the same service.

Q. Why is it not good practice to connect an old set of four cells in series-multiple with a new four-cell battery, or groups of uneven numbers in the same manner, as for instance, three in one and four in another?

A. The new cells will have an output of twice that of the old ones, so that when the circuit is closed they will discharge through the latter until the amperage of all is equalized. Where uneven numbers are used in groups in series-multiple connection, the voltage of the larger will be superior to that of the smaller, and a similar action will take place on open circuit so that in a short time the maximum potential of the battery will be that of the weakest group.

Q. Why should one cell much lower than the others never be included in a dry-cell battery?

A. For the reason just given above, as well as the fact that an exhausted cell increases the resistance of the battery as a whole and decreases the current.

Q. Why will the dry-cell battery used on a dual ignition system not run the engine satisfactorily for any length of time when the magneto is not in proper working order?

A. Because the interrupter, or contact breaker, of the magneto is of the closed-circuit type, thus drawing current continuously, except when the points open to break the circuit and induce a high-tension current in the secondary of the coil. In a system of this type, the dry cells are intended only for starting purposes.

Q. Why can a modern battery system not be used with dry cells?

A. Because the interrupter is of the closed-circuit type, similar to that of the magneto, and the demand for current (usually about 3 amperes) is practically constant. It is not so much the amount of current required that affects the dry cells, as the fact that they are almost constantly on closed circuit, so that there is no opportunity for the depolarizing agent to work. This demand on the storage battery of the starting and lighting system (usually of 80- to 120-ampere-hours capacity) is negligible. At a 3-ampere discharge rate, the larger battery when fully charged and in good condition would be capable of giving practically forty hours of continuous service. Under the same conditions, new dry cells would not provide efficient ignition for more than an hour.

Q. Does the voltage, as well as the amperage, of the dry cell fall off on closed circuit?

A. The voltage is affected very slightly; a cell that is practically exhausted will show almost $1\frac{1}{2}$ volts so that a voltmeter test is no indication of the condition of the cell.

FORD IGNITION SYSTEM

While a great many of the causes of missing or breakdown, in the ignition system covered by the foregoing queries, apply to a great extent to all cars, such as loose wires, short-circuits and the like, the Ford system is distinctive. It is based on the same fundamental principles, of course, but it has many features not to be found on other cars so that there are causes of failure that could never be readily determined by experience gained on other makes of machines, though long handling of ignition apparatus would naturally be of great assistance. In working on the Ford ignition system it must be borne in mind that it is a combination of the old-time battery system with a modern generator as the source of current supply, so that the many defections due, in the earlier days to the dry battery, are now lacking.

Q. Of what does the Ford ignition system consist?

A. A multipolar alternating-current generator (magneto) built integral with the flywheel; a primary, or low-tension timer, in which a roller makes contact with the four stationary segments in the housing; four vibrator coils, one for each cylinder, plus the usual number of spark plugs and connections in the primary and secondary circuits.

Q. Is the Ford ignition system efficient and reliable, or is it advisable when much trouble is experienced with it to replace it with any of the numerous accessories and complete ignition systems that are claimed to be improvements?

A. While there are many ignition systems the parts of which are made with greater precision, and some in which the design and particularly the accessibility of the important essentials are superior, experience has proved the Ford system to be both efficient and reliable. With proper care, there should never be any necessity for replacing it with any system made by an accessory manufacturer, or for adding to it any one of the legion of devices advertised as improvements on it.

Timer

Q. What are some of the commoner causes of failure of the Ford system?

A. One of the most frequent is due to the timer and is caused by failure to lubricate it. Contrary to the usual practice, which is to prevent oil getting on the contacts of a timer as it tends to insulate the latter, the Ford timer requires plenty of oil, and should be lubricated every day. There is no fear of giving it too much oil as the excess will leak out of the housing; it will continue to operate satisfactorily even though flooded with oil, while the slightest lack of it will cause trouble.

Q. What is the nature of the trouble caused by the timer?

A. If not oiled at regular intervals, it will cause missing of various cylinders, and those that do fire will be late, as if the ignition were fully retarded, so that the motor develops very little power. An accumulation of gummed oil and dirt will produce a similar result. The timer housing should be taken off and the contacts cleaned; the roller contact also should be cleaned by squirting gasoline over it and wiping over well.

Q. Will lack of oil have any other result?

A. Besides the missing, usually most noticeable at higher speeds, failure to lubricate will result in very rapid wear of both the roller and its track (contacts in the stationary housing) so that its operation will soon become unsatisfactory, even though subsequently kept oiled.

Q. What are some other causes of faulty operation of the timer (generally referred to as a commutator)?

A. Weakening of the spring which holds the roller against its track will cause missing at low speeds, while a loosening of the spring which holds the timer housing in place is liable to cause erratic firing at all speeds. This spring is held by a single cap screw passing through the breather tube, which serves also as an oil filler for the crankcase. At its inner end it has a small boss which fits in a corresponding depression in the hub of the timer housing. This is the only thing that holds the latter in place. The loosening of this cap screw is liable to let the housing drop out of place sufficiently to prevent the roller making contact with all of the segments.

Q. Does the weather have any effect on the operation of the timer?

A. Unless precautions are taken to lubricate it properly, cold weather will make starting difficult. This is due to ordinary lubricating oil becoming congealed in the housing, thus preventing the roller from coming into good contact with the segments. An indication of this sometimes is that the motor will fire only on two or three cylinders for several minutes after being started and will thereafter fire regularly, the oil then having become liquefied again.

Q. How can the timer be removed?

A. Take out cotter pin from end of rod which attaches it to the spark-advance lever on the steering column, and detach this rod. Loosen cap screw passing through breather pipe on top of the timing gear cover. This releases the spring which holds the timer housing in place, and the latter can be easily removed. To remove roller contact, unscrew lock nut, withdraw steel brush cap and drive out the retaining pin. The brush can then be lifted from the camshaft. In replacing it, care must be taken not to alter the timing of the ignition. The upper contact of the housing represents cylinder No. 1, and the exhaust valve of that cylinder should be closed when

the brush points upward. This may be determined by removing the valve mechanism cover and noting the operation of the valve in question.

Q. If parts show much wear, what should be done?

A. Replace them; as they cost so little that it is far less expense to put in new parts than to attempt to make old ones serve by truing them up.

Q. When examination reveals gummed oil and the weather is cold, what should be done?

A. Clean out the housing and the roller-contact parts with gasoline, and use a mixture of $\frac{1}{4}$ kerosene and $\frac{3}{4}$ lubricating oil in the timer, as long as the weather is cold.

Q. What other causes of trouble with the timer are more or less common?

A. Short-circuiting of the primary wires which lead to the timer, or the loosening of these wires at the terminals on the housing. The position of the timer is such that the insulation of these wires is subjected to considerable wear by reason of the movement of the housing in advancing and retarding the time of ignition. The best method of remedying this is to replace the entire set of primary wires.

Vibrator Coils

Q. Is irregular firing likely to be caused by any other part of the system than the timer?

A. The vibrators of the induction coils may get out of adjustment and cause either erratic firing, or missing of one or more cylinders altogether, in case one or more vibrators cease to operate.

Q. How can this be determined?

A. Run the motor slowly and watch the action of the vibrators; they should act regularly and with the same rapidity in each case, any stuttering or hesitation indicating either poor adjustment or points in poor condition.

Q. How can the vibrators be utilized to determine which cylinder is missing, where the cause lies in some part of the system other than the vibrators themselves?

A. Hold one vibrator down at a time with the finger; if the remaining three cylinders fire regularly, the one represented by the vibrator being held out of action is the one at fault. The cylinder can always be located quickly by holding down each vibrator in turn.

Q. When the cylinders do not all fire regularly, but there is no perceptible difference between the action of the vibrators, how can the cylinder, or cylinders, at fault be determined?

A. Hold down the vibrators in pairs, taking first Nos. 1 and 4, and then Nos. 2 and 3. This will cause the engine to run on two cylinders at a time, and any difference between the operation of the two pairs or between members of each pair will be apparent.

Q. What is the firing order of the Ford motor?

A. 1-2-4-3.

Q. How are the coil vibrators adjusted?

A. The usual method is to turn the adjusting screw up until the vibrator stops buzzing; then turn the screw down again very slowly until the points just come together and the firing of that cylinder becomes regular; then give the screw an extra quarter-turn down, and lock in place.

In adjusting K-W coils, it is important to see that the little flat-cushion spring just underneath the vibrator bridge works back and forth every time the points make and break contact. This can be determined by taking the coil unit out of the box and holding the vibrator up to the light; press down the vibrator and observe the action of the cushion spring. It is important to adjust all the units alike or the motor will not develop its full power.

Q. What is the effect of adjusting so that the contact points are too far apart; too close together?

A. If too far apart, the cylinder will not fire regularly or with its usual power. If too close together the current is likely to arc at the contact points, thus preventing the breaking of the circuit when the armature is drawn down, burning the points themselves, and sometimes putting the coil out of action entirely.

Q. Does the vibrator adjustment affect starting?

A. When the points are too close, more current is required to "make and break" the contact between them, and the motor must be turned over that much faster. For the best adjustment, the points should barely touch. If the adjustment is too light, they may not do this and a miss at that cylinder will result.

Q. If the vibrator buzzes constantly, what is the trouble?

A. There may be a short-circuit at the timer or in the wire leading from that coil to it, or the coil itself may be defective. One

of the first symptoms of a defective coil is the buzzing of the vibrator, with no spark at the plug.

Q. How can a defective coil be determined?

A. To make certain that the cause is in the coil, change the location of the units in the coil box. If another unit acts the same when substituted for the one giving trouble, the fault is not in the coil but in some other part of the system. Should the coil that is shifted, however, act the same in its new location, and the one that takes its place operates properly, the coil itself causes the trouble.

Q. When there is an unusually heavy or "fat" bluish spark at the contact points, what is the cause?

A. The current may be arcing at the points, due to their being adjusted too closely; or the condenser may have broken down. To make certain that the condenser has failed, disconnect the secondary cable from the spark plug and hold the terminal about $\frac{1}{32}$ inch away from the metal end of the plug. If the condenser has failed, the spark occurring at this gap will be irregular.

Q. What will happen if the contact points are allowed to become pitted and ragged, due to the burning effect of the current?

A. They are liable to stick together and cause unnecessary difficulty in starting or occasional missing when running. They should be trued up with a very fine flat file or with an old piece of fine sandpaper. Never use emery.

Q. When the vibrator points burn badly in a very short time, what is the cause?

A. The owner of the car has probably replaced the original vibrators with cheaper substitutes having nickel or German-silver contact points. Nothing but platinum or platinum-iridium contacts will give satisfactory service, so that new parts from the makers should be installed.

Q. When the engine will suddenly lag and pound, what is the cause?

A. An intermittent short-circuit in the wiring or at the commutator. The pounding is caused by the premature explosion of the charge against the rising piston. The vibration causes the short-circuit to occur at some times, and not at others, so that the engine will run regularly for a few minutes and then pound again, until the movement once more temporarily eliminates the cause.

Q. With all the vibrators properly adjusted and the timer and wiring in good condition, what is the cause of irregular firing?

A. Provided the spark plugs are all in good condition, points not too far apart, etc., this is frequently caused by the top of the coil box coming loose. The coil units are provided with brass-strap terminals on the bottom of the wooden casing of the coil, and these terminals make contact with similar straps in the bottom of the coil box on the dash. They depend for good contact on the pressure exerted by the cover of the box, which must always be kept tightly snapped on.

Q. When missing is not traceable to any of these causes, what is likely to be the cause?

A. Something outside of the ignition system, such as a weak-valve spring, or a valve improperly seating, due to some other cause. Loss of compression at the cylinder-head gasket: run a little lubricating oil along the edge of the gasket and note whether bubbles appear. Replace with a new gasket if any leakage is apparent.

Magneto

Q. How does the Ford magneto differ from the regulation type?

A. The *magnets* are revolved instead of the *armature;* it has sixteen field poles and armature coils, and it revolves at crankshaft speed to fire a four-cylinder motor. It is not timed to the motor the same as an ordinary magneto, which is coupled to the camshaft, or other half-time shaft, and the distributor of which must rotate synchronously with the motor.

Q. Of what does it consist?

A. Two discs, one carrying sixteen magnets with their poles pointing outward, and the other sixteen coils of strap copper on oval cores, all of the coils being connected in series. The disc carrying the magnets is rotated by the flywheel to which it is attached, while the other disc is attached to the crankcase, and remains stationary. One end of the coil winding of the magneto is grounded on the supporting disc carrying the coils, while the other is led to a terminal which extends through the flywheel housing. A cable from this terminal or binding post, supplies current to the coils.

Q. Is it ever necessary to remagnetize the magnets of the field, and how can it be done?

A. Unless they have become demagnetized, due to some outside influence, it is rarely necessary to touch the magnets.

Q. How can they become demagnetized by an outside force?

A. The attachment, by mistake, of a storage battery to the magneto terminal will send a current through the coil windings in the opposite direction, and will demagnetize them. When this happens, it is not advisable to attempt to remagnetize the old magnets, as it is much cheaper and quicker to replace them. The new set is supplied mounted on a board in exactly the position they should be installed.

Q. How can the magneto be dismounted?

A. To do this, it is necessary to remove the power plant from the car. The radiator must be taken off by disconnecting its stay rod and taking out the two holding bolts at the frame, after uncoupling the hose connections. Remove the dash and loosen the steering-post bracket, fastened to the frame, permitting the dash and steering gear to be lifted off as a unit (wires having first been disconnected); take out bolts, holding front radius rod in socket underneath the crankcase; remove four bolts at the universal joint; remove pans on either side of cylinder casting; disconnect feed pipe from carburetor, and exhaust manifold from exhaust pipe, by unscrewing large brass nut; remove the bolts which hold the crankcase arms to the frame at the side; then pass a rope through the opening between the two middle cylinders, and tie it in a loose knot; through the rope pass a 2 by 4 timber or a heavy iron pipe about ten feet long; with a man at each end of this and a third at the starting crank, the whole power plant can readily be lifted out; then remove the crankcase and transmission cover, and take out the four cap screws that hold the flywheel to the crankshaft. This gives access to every part of the magneto mechanism. To take out the old magnets, simply remove the cap screw and bronze screw which holds each in place. When reassembling the magneto, great care must be taken to see that the disc or plate carrying the magnetos revolves them exactly $\frac{1}{32}$ inch of the core faces of the coils.

Q. How can it be determined whether the magnetos are at fault or not?

A. Whenever there is a partial failure of the current, remove the binding post by taking out the three screws which hold it in

place. Clean out any dirt or foreign matter that may have accumulated under the contact spring. If this does not materially improve the running, test by comparing with battery ignition. Connect one terminal of a six-volt storage battery to the battery terminal on the coil box (a battery of four or five fresh dry cells will serve equally well for a short test run), and ground the other terminal of the battery on the frame of the car, making certain that good electrical connection is made. Run the engine at different speeds on the magneto, and, while running, throw the switch over suddenly to the battery point; any decided acceleration in the speed will indicate that the battery is supplying a much better current for ignition, and that the magneto is at fault. If used for any length of time for testing, a dry-cell battery will not give equally accurate results, as the cells are likely to run down very quickly, and the firing will then be better on the magneto, even though the latter be weak.

Q. When the engine suddenly fails to fire altogether, what is likely to be the cause?

A. The cable leading from the binding post on the magneto has dropped off, either at the latter or at the coil; or some piece of foreign matter has come between the contact spring attached to the binding post and its contact.

Q. When the magneto gradually gets weaker and weaker in a car that has seen a great deal of service, is it certain that the magnets have weakened?

A. Not necessarily; the adjustment of the bearings may be permitting the disc carrying the magnets to revolve further away from the armature coils than intended. Any increase in this distance, even though small, will have a decided effect on the output of the magneto.

GENERAL CAUSES OF IGNITION FAILURE

Q. When the motor stops very suddenly without any apparent cause, what is likely to be the cause of the trouble?

A. A break in the current-supply circuit of the ignition system, or sudden failure of the ignition current, due to any other cause.

Q. In how many different ways may this occur?

A. A feed wire from the battery may part from its terminal, either at the battery or at the coil; the ground wire may become dis-

connected at either end; in a dual system, the primary cable from the magneto to the coil may become disconnected, either at the magneto or at the coil; the secondary cable from the coil to the magneto distributor may loosen and drop off, either at the coil or at the magneto; this secondary cable may become grounded between the coil and the magneto; the switch may have loosened up, through vibration, and may jar open; the magneto may have become grounded internally, so that no current is delivered to the outside circuit. The magneto cam may have loosened up on its shaft, so that it no longer revolves with the latter, and, consequently, does not open the contact points in the breaker box. The primary cable from the magneto to the coil may have become grounded on the frame or short-circuited on another cable, due to wear from chafing, thus preventing the current from reaching the coil. In a dual system, the entire system may have become grounded through the metal of the dry cells coming in contact with the metal battery box or other metal part connected to the chassis of the car.

Q. Do the foregoing constitute all of the possible causes for a sudden failure of the ignition system?

A. No brief résumé could possibly include all of the causes that may exist for a stoppage of this kind, but they include probably more than 90 per cent of all the commoner causes of such a failure, and, either as given above, or in some modified form of the same condition, will be found to represent by far the greater part of all the causes of sudden stoppage.

Q. Of the causes given above, which are the most likely, in the order of their usual occurrence?

A. The loosening of a battery connection at the terminal or at the coil, or of a magneto and coil connection at either end; grounding or short-circuiting of either the primary or secondary main connection between magneto and coil, that of the secondary being more frequent owing to the high-tension current it carries. Grounding of the dry cells in the battery box; loosening of the switch so that it jars open. With the exception of the grounding of the primary or secondary cable between the magneto and the coil, all of the above are the direct result of vibration and jarring. In old four-cylinder motors, vibration is constant, and at times very severe, so that attention should first be directed to searching for loose con-

nections, as unless tightened up at intervals, they are very likely to shake off. Internal grounding of the magneto or loosening of the breaker-box cam, so that the interrupter does not operate; these are rarer causes of trouble, and a search for them should be deferred until after the commoner causes mentioned above have been thoroughly investigated.

Q. Where all connections have been tightened up without overcoming the trouble, how can the other possible causes of stoppage be eliminated, in tracing the real seat of the failure to run?

A. See that the dry batteries of a dual system are not touching any metal; inspect the magneto breaker box while another person slowly turns the motor over by hand, so that the operation of the interrupter may be noted. If working properly, disconnect the secondary cable from the magneto to the coil, and with the motor running, hold its terminal $\frac{1}{4}$ inch away from the coil connection. In case there is no fault here, a bright spark will result at the gap. Note whether holding the cable away from the motor has been responsible and whether, when it is dropped back on the motor again, sparking occurs at any point along its length between the cable and the metal of the motor. Disconnect the primary cable from the magneto to the coil, and, with the motor running, wipe its end on the primary terminal of the coil; sparking should result if there is no break in the cable. Take the same precaution in putting it back as with the secondary cable to see that it is not grounding at some place along its length where it touches the motor. No visible spark will be produced in this case, but the condition of the insulation of the cable itself should be the best indication of this kind. Bend the wire along its length to detect any possible breaks in the copper wire under the insulation. Disconnect the ground cable from the coil to the magneto, and, while the motor is running, hold it close to either the magneto or the coil terminal; a high-tension spark will result if the cable is all right. Note, while the motor is running, whether there is any sparking at the safety gap, on the magneto itself, if on the high-tension type, or on the coil of a dual system. Note whether the primary and secondary cables cross each other, and whether there is any sparking between the two while the motor is running. Inspect the ends of all stranded cables carefully, and see whether one or more of the fine wires have not broken through

the insulation and become bent over, so as to ground the cable on some adjacent metal.

Q. Is a sudden stoppage of the motor likely to be due to any cause other than a failure of the ignition system?

A. One possible cause is the sudden and complete stoppage of the carburetor spray nozzle, but, even in this case, the failure of the motor will not be so sudden nor so complete as where the ignition current has been cut off, as the motor will continue to fire, for a few revolutions on what fuel mixture remains in the manifold. There is practically no other cause for the motor suddenly stopping.

Q. When, instead of stopping completely, the motor will fire regularly for a few minutes, hitting on all cylinders, and then begins to miss spasmodically, how can it be determined whether the fuel-supply system or the ignition is at fault?

A. The fact that, under such circumstances, the motor will fire regularly for a little while and then miss very badly, and, a few minutes later again take up its operation smoothly, is usually an indication that the ignition system is working properly, but that at intervals there is a failure of the fuel supply. One of the commonest causes of this is the exhaustion of the main supply of gasoline in the tank. On the last half-gallon or so of fuel there is no longer a regular supply to the carburetor, with the result that, with the motor running at speed, what gasoline is in the carburetor is practically exhausted in a few minutes. During this period, however, the motor will continue to run regularly. As it lowers the level in the carburetor float chamber, an insufficient supply is drawn through the nozzle and the motor misses badly, and slows down almost to the stopping point. This permits a new supply to fill the carburetor, and the motor once more runs properly. It is the extremely intermittent nature of the firing, with first one cylinder missing and then another while the carburetor is refilling itself from what little gasoline remains in the tank, that makes this appear very much as if it were due to failure of the ignition. Under conditions such as this, always inspect the fuel supply first. With an ample supply of gasoline in the tank, a partial clogging of the spray nozzle of the carburetor, due to some obstructions which is intermittently drawn up into it by the suction and again drops back, will give exactly the same symptoms of ignition trouble.

Q. Are symptoms of this nature ever due to a fault in the ignition system?

A. They will result at times from the use of a set of dry cells that is almost exhausted. The storage battery also acts in a similar manner. Both the dry cell and the storage battery recuperate very rapidly even when practically exhausted, so that they will often provide sufficient current to run the motor properly for a very short time, will then cause it to miss badly, and shortly afterward again run regularly. If, when the switch is thrown over to the magneto, the motor runs smoothly and continuously, there is no doublt that the battery is at fault, and this may be verified by testing the cells with a pocket ammeter. Should they show much less than eight amperes on test, they are the cause of the trouble and should be discarded. This may also be due to the use of a storage battery that is practically exhausted, though it would be extremely bad practice to allow a storage battery to get this low. Test with the voltmeter: if the cells show $1\frac{1}{2}$ volts each or less they are badly in need of charging, and if they will not run the motor properly, should be immediately recharged from an outside source of current.

Q. What is meant by "pre-ignition", and what causes it?

A. When the charge in the cylinder is ignited before the passing of the spark at the spark plug, it is said to be "pre-ignited", i.e., fired in advance of the proper time. As a result, the force of the explosion is partly exerted against the rising piston, as is evidenced by a heavy pounding accompanied by a decrease in the power. The cause is usually an accumulation of carbon in the form of a deposit on the piston head and results from excessive lubrication. The surplus oil finds its way into the combustion chamber and is burned. This condition is further aggravated by running with an over-rich mixture. If the motor is allowed to run very hot, these carbon deposits become incandescent, so that the fresh mixture is fired the moment it comes in contact with them. In some cases this becomes so bad that the motor cannot be stopped without shutting off the gasoline supply.

Q. How can the pounding caused by pre-ignition be distinguished from other internal noises, such as those produced by a loose crankshaft or crankpin bearing?

A. Pre-ignition takes place only after the motor has been

running long enough to become very warm and with the throttle opened to any extent the pounding is very violent, jarring the whole chassis. The noise produced is distinctive and can be identified readily once it has been experienced. Unless very loose, a bearing noise will practically disappear if the motor is allowed to idle very slowly and will always increase in proportion to the load, becoming very severe when climbing a hill.

Q. How can the condition which causes it be remedied?

A. By removing the carbon deposits. In many late-model engines this can be done most readily by removing the cylinder heads, usually a single casting. The carbon may be burned out with the oxygen-gas flame now in common use or it may be loosened by the use of kerosene in the motor. After the motor has run long enough to become hot, shut off the gasoline supply gradually, meanwhile feeding kerosene through the auxiliary-air inlet of the carburetor until the motor is running on kerosene alone; feed an excess of the latter and the carbon will be loosened and blown out through the exhaust.

Q. When a single cylinder continues to miss regularly, all the others running properly, and inspection shows every part of the ignition system to be in good condition, what is likely to be the cause?

A. Failure of its valves to operate properly. Either the inlet or the exhaust valve is not opening, or is sticking open (the result will be the same in either case). This may be caused by a weak valve spring, a bent valve stem, derangement of the valve tapper, so that it does not strike the valve-stem end, or by a piece of foreign matter, such as a piece of carbon, lodging on the seat of the valve, so that the latter cannot close. Another, though rarer cause, is a leak in the manifold, close to the inlet valve of the cylinder in question. This permits an excessive amount of air to be drawn into that particular cylinder, so that the charge is too weak to fire. In any of the above cases, the result is that fuel either does not get into the cylinder or it is exhausted before it can be fired, as with every part of the ignition system working properly, the only thing that can cause a cylinder to miss is lack of fuel.

Q. Mention one of the causes of irregular firing that is seldom suspected, except by those who have experienced it previously?

A. Excess oil finding its way into the combustion chambers in such quantities that it covers the spark-plug electrodes, thus preventing a spark from jumping the gap. The oil, particularly when fresh, is an excellent insulator and, if mixed with carbon so that it conducts the high-tension current, it does so without permitting the formation of a spark. Owing to the viscosity of heavy lubricating oil, it clings to the spark-plug points and when they are as close together as they should be ($\frac{1}{32}$ inch), it will often bridge the gap for some time, despite the vibration and succeeding compressions in the cylinder. This fault is particularly difficult to locate when not suspected, as jolting over a rough piece of road will shake the plug points free and the engine will fire regularly, again missing intermittently when on smooth going once more. When confined to one cylinder, it is usually an indication that the cylinder wall is scored, or that the lubricating-oil feed to that cylinder is deranged.

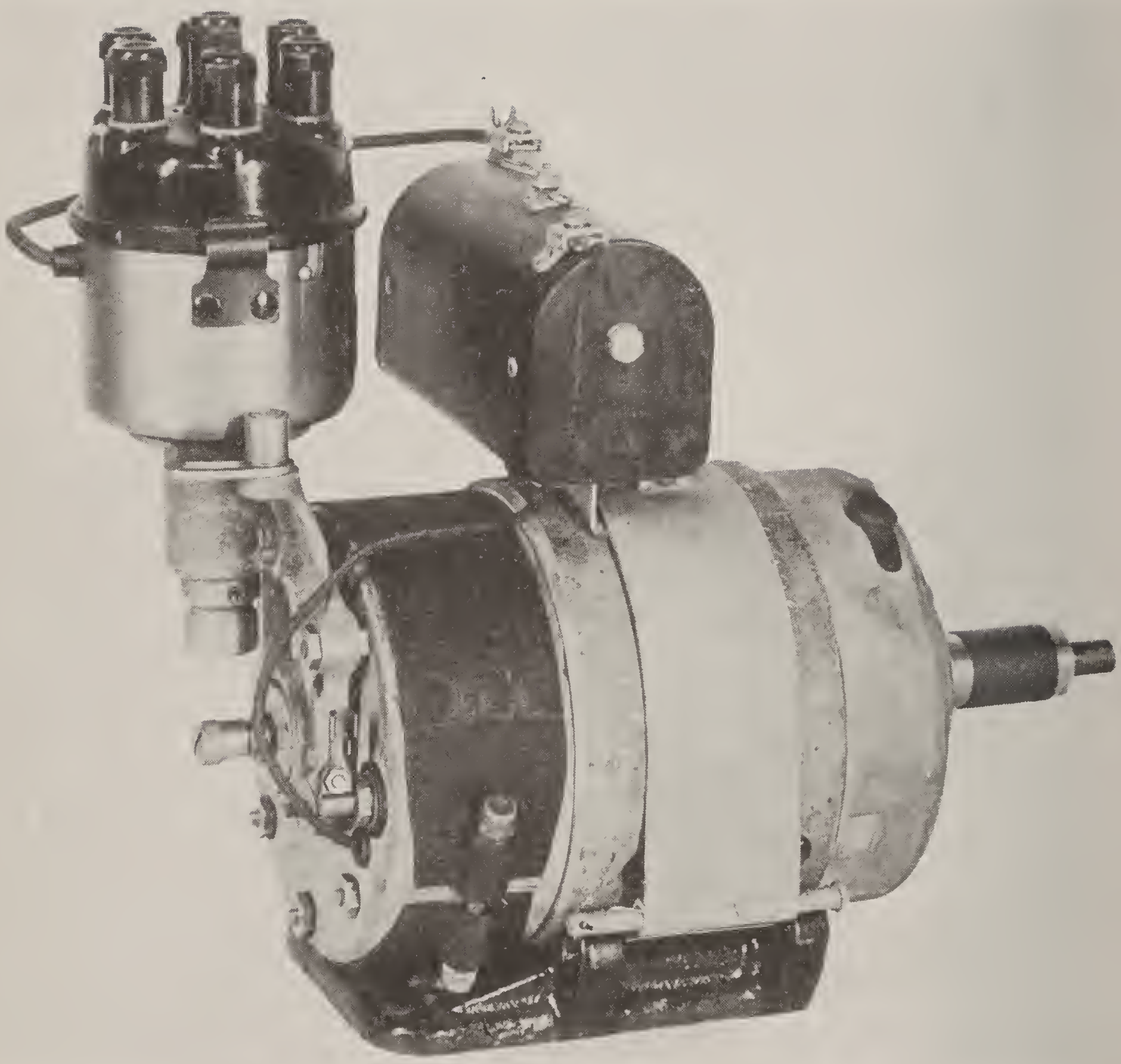
Q. Mention a rare cause of what appears to be ignition failure?

A. When a motor has been taken down and all its working parts thoroughly cleaned with gasoline or kerosene, it will sometimes be found next to impossible to start it. The explosions are very weak and erratic, and the engine does not generate sufficient power to run more than a few revolutions at a time. The trouble has every indication of being due to a derangement of the ignition system and looks particularly as if it might be faulty timing, caused by misplacing the spark-plug leads. In one case of this kind experienced by the writer, all the spark plugs and wiring were renewed, fresh batteries put in, and every part of the ignition system checked by three experienced garage men, but the motor could not be made to run. The trouble was finally overcome by taking out the spark plugs and injecting two or three ounces of the heaviest cylinder oil into the combustion chambers. The motor was old and well-worn so that the pistons were loose; the cleaning process left all these parts wet with kerosene and there was enough of the latter left in the crankcase to thin out the fresh lubricating oil considerably. As a result there was no compression, and the force developed by the explosion was not sufficient to turn the motor over for more than a few revolutions; what little oil was splashed up by this was too thin to seal the space between the pistons and cylinders so that most of the

power generated by the weak explosions leaked past the pistons. Trouble of this nature is most likely to occur in old and well-worn motors, and will sometimes result from excessive priming with gasoline, i.e., squirting gasoline in through the petcocks or spark-plug holes, as this washes all the lubricating oil from the cylinder walls into the crankcase and thins the oil in the latter.

Q. When intermittent failure of the ignition is thought to be due to faults in the wiring which cannot be detected by an ordinary examination, how can the trouble be found most readily?

A. Fit a handy length of cable—one that will span practically any two points in the ignition system—with spring-clip terminals. Disconnect each wire in turn, and substitute for it this length of cable as a temporary connection; satisfactory operation with the latter indicates that the wire it replaces is at fault.



TYPICAL LIGHTING AND IGNITION GENERATOR, 1917 DELCO TWO-UNIT SYSTEM AS USED ON COLE, OAKLAND, AND OLDSMOBILE EIGHT-CYLINDER MODELS

Courtesy of Dayton Engineering Laboratories Company, Dayton, Ohio

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART IV

ELECTRIC STARTING AND LIGHTING SYSTEMS

GENERAL FEATURES

Fundamental Characteristics. In the introduction to elementary electric principles, no attempt has been made to go beyond simple theory as applied to the generation of electric currents, the operation of electric motors, circuits and the auxiliary devices required by the lighting and starting systems employed on the automobile. A very large part of the theory of electricity and electrical action as given in the majority of textbooks is omitted altogether for the sake of clearness, only that part of it which bears directly on the subject of electrical equipment of the automobile being retained. In the presentation of the latter, a somewhat different method of handling the subject has been followed, particularly with a view to making it appeal to the practical man by citing examples and comparisons, the force of which is at once clear. The man whose time for study is limited has no opportunity to go into all branches of electrical phenomena, so that the subject is presented in the briefest and most practical manner.

Considering that the practical application of electric lighting on the automobile dates back to 1910 only and electric starting to 1912 models, in which year but one make of car was fitted with a complete system as regular equipment, there are a number of different types in use. Each is characterized by varying features of design in the generators, motors, and auxiliary devices. In many instances these are slight, in others they are radical, but in every case they merely represent a different application of the fundamental principles given in the introduction. Since they must first pass the test of practical use before being adopted by the automobile manufacturer, they all operate successfully. But, that they all do not

operate equally well, or, to put it better, all do not continue to show the same high degree of efficiency and reliability in service, goes without saying. Owing to the lack of standardization that prevails, it is necessary to become familiar with each system. A brief analysis of each of the systems in general use accordingly is given here, and it will be found valuable for reference.

VARIATIONS OF OPERATING UNITS AND WIRING PLANS

Principal Differences. Before taking up the different systems in detail, an outline of the chief points on which they vary is given as an aid in distinguishing them when found in service on the various makes of automobiles of which they form a part. Electrical systems as a whole may be divided into two general classes. These are the single-unit and the two-unit types.

Single-Unit Type. The first type is characterized by the employment of a *dynamotor*—a single unit with generator and motor windings on the same armature and fields connected to independent commutators at each end of the armature, as in the Delco, (in some models, two concentric commutators at the same end) or to the same commutator, as in the Dyneto. The single-unit type is greatly in the minority, the two makes cited being the chief exponents of it, though both of them are also built in the double-unit type as well. When the ignition distributor is incorporated in the generator, as is now very generally the case, the single-unit types incorporate in one machine the three chief electrical functions required on the automobile, viz, charging the storage battery, turning the engine over to start, and distributing the ignition current.

Two-Unit Type. Owing to the difficulty of efficiently combining in one machine two functions so widely separated as the generation of a constant charging current of a value rarely exceeding 20 amperes, and the utilization of currents up to 350 amperes, such as are required for starting, the majority of systems are of the two-unit type. The latter also is generally favored owing to its greater convenience of installation, as the dynamo must run either at motor speed, or at $1\frac{1}{2}$ times that, while it is necessary to gear the starting motor to the engine in the ratio of 30 or 40 to 1. As the term implies, an independent unit is employed for keeping the storage battery charged, lighting the lamps (when running), and

distributing the ignition current, while a second unit is installed solely for the purpose of turning the gasoline engine over to start.

Single-Wire and Two-Wire Systems. The difference between these is pointed out in detail in the section on Wiring Diagrams, Part IV. Owing to its greater simplicity of installation, reduced cost for wiring, and the greater ease with which faults may be located, the single-wire system is largely in the majority. In fact, there are only one or two examples of two-wire systems in general use, of which the Bijur, as employed on the Packard, Jeffery, and other cars, may be cited as an instance. In the gradual approach to standardization that is being made each year, the number of cars on which the single-wire system is employed is constantly increasing. But differences will be found in these single-wire systems as well, some employing the frame of the car for the positive side of the circuit, and others for the negative. This must be borne in mind when testing for faults with the volt-ammeter.

Comparison of Systems. While inherently more dangerous, experience has demonstrated that the fire hazard with the single-wire system is more a matter of proper installation than of the comparative merits of the systems themselves, and quite a number of manufacturers who adopted the two-wire system at the outset have later become converts to the single-wire system. In fact, while the Society of Automobile Engineers has not adopted the latter as recommended practice up to the present writing, although the subject has been under investigation for almost three years, the majority of automobile makers have taken it as their standard construction, and it seems more than likely that the others will do so before long. Considerations of economy demand this on the lower-priced machines, as the cables employed are so expensive as to make a substantial difference in the cost per car for the electrical equipment where the single-wire standard is employed. It does not follow from this that where the maximum of safety and efficiency are to be attained regardless of cost, the two-wire system is always employed, as, after experiencing considerable difficulty with it, the makers of the Pierce-Arrow adopted the single-wire system. The Packard, on the other hand, employs the double-wire system, and the advantages in simplicity of the single-wire may be noted by comparing the Packard installation, as shown in Fig. 144,

with the Delco single-wire system, Fig. 145, which is employed on a great number of cars. Comparison cannot be made exactly on the

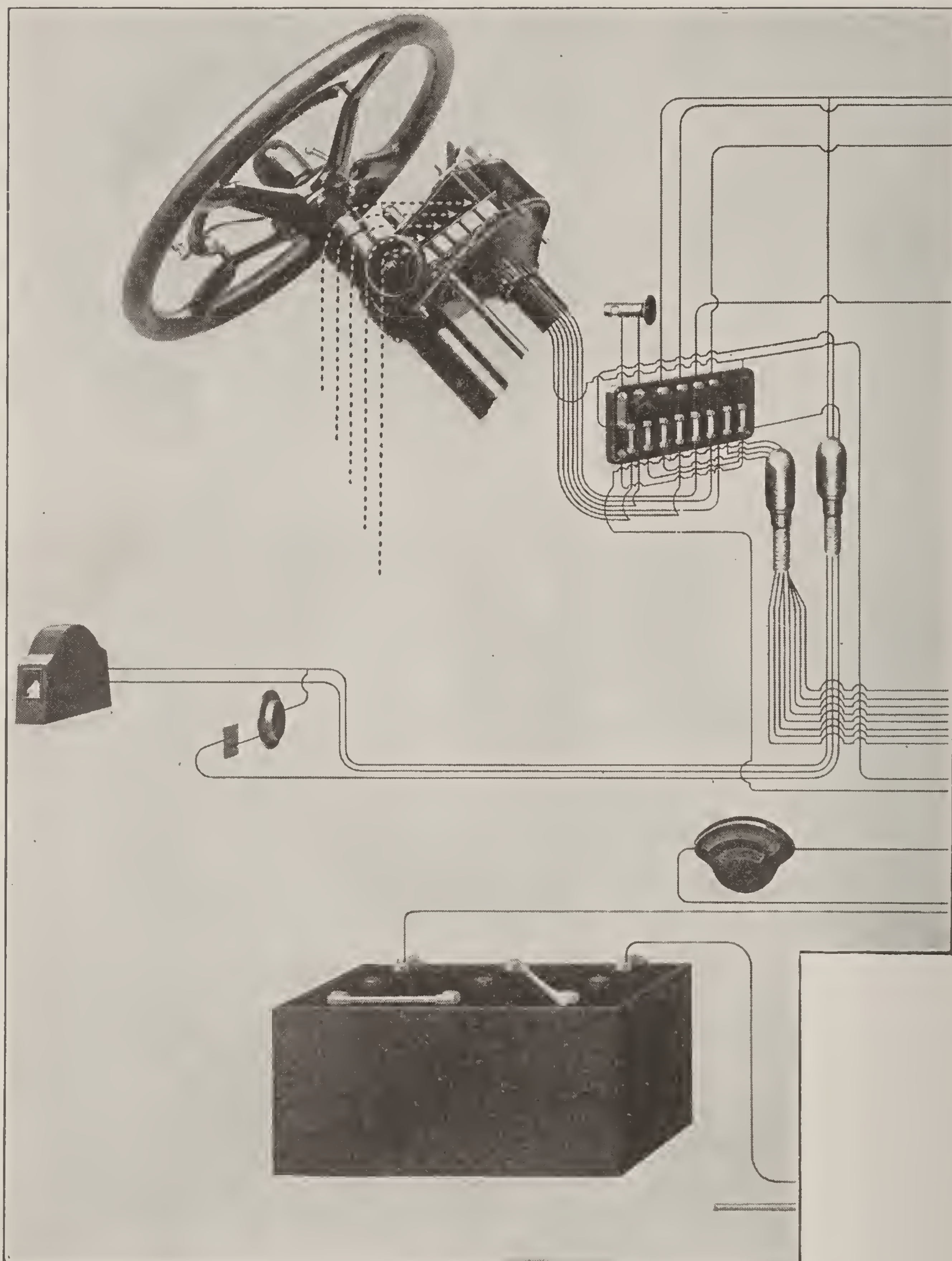
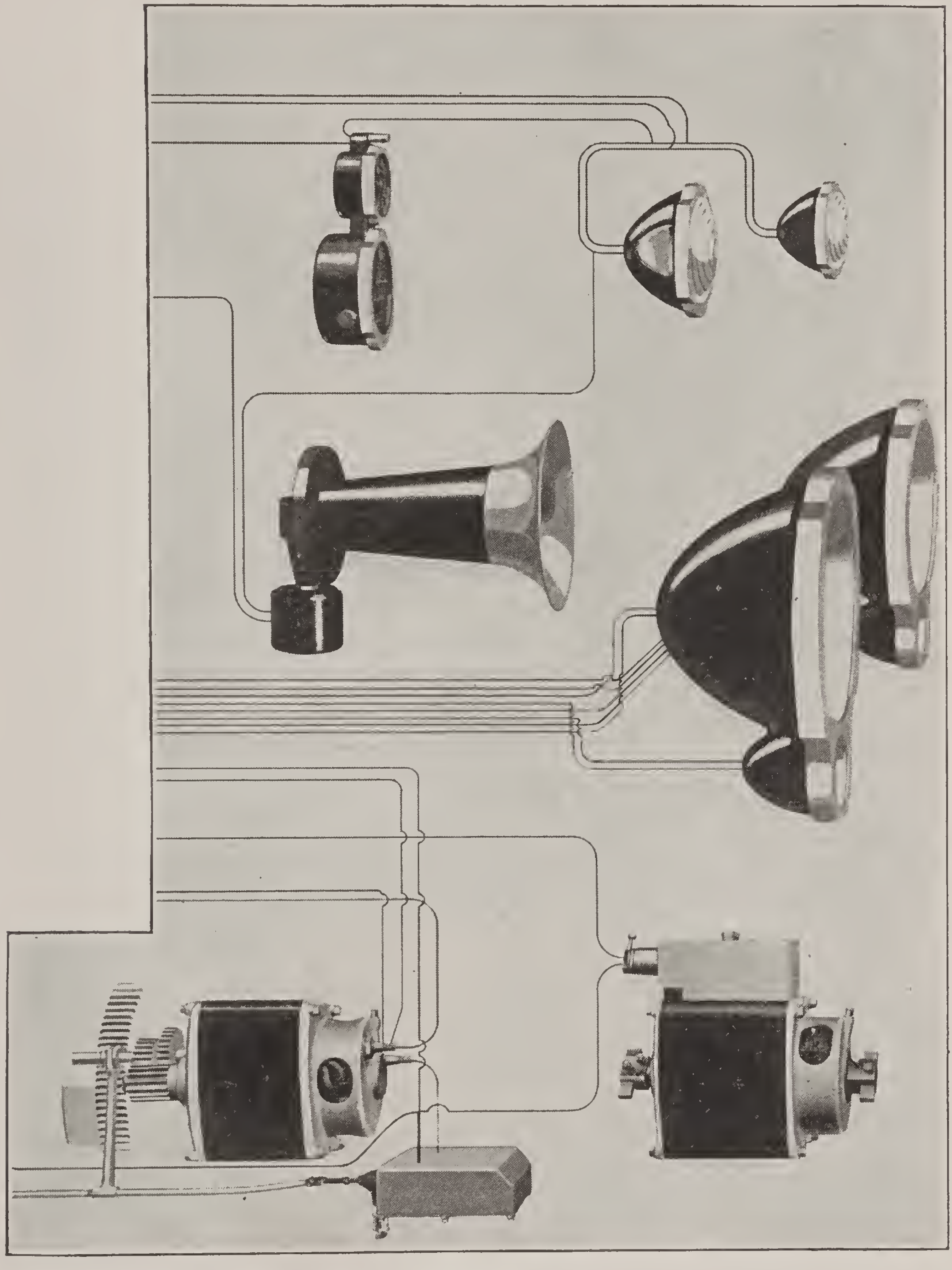


Fig. 144. Wiring of Packard (Bijur) Two-Unit.
Courtesy of Packard Motor Car

same basis in these two installations, however, as the Packard is what is known as a two-unit system, i.e., the generator and the electric starting-motor are independent, while the Delco is a com-

bination generator, motor, and ignition unit. Moreover, the Packard has several additional lamps, being fitted with double bulb



Two-Wire Starting and Lighting System (1916 Model, Six-Cylinder)
Company, Detroit, Michigan

headlights and side lights, which are not present in the Delco installation; but even omitting these considerations, it will be seen that the single-wire system has the advantage of simplicity in a marked degree.

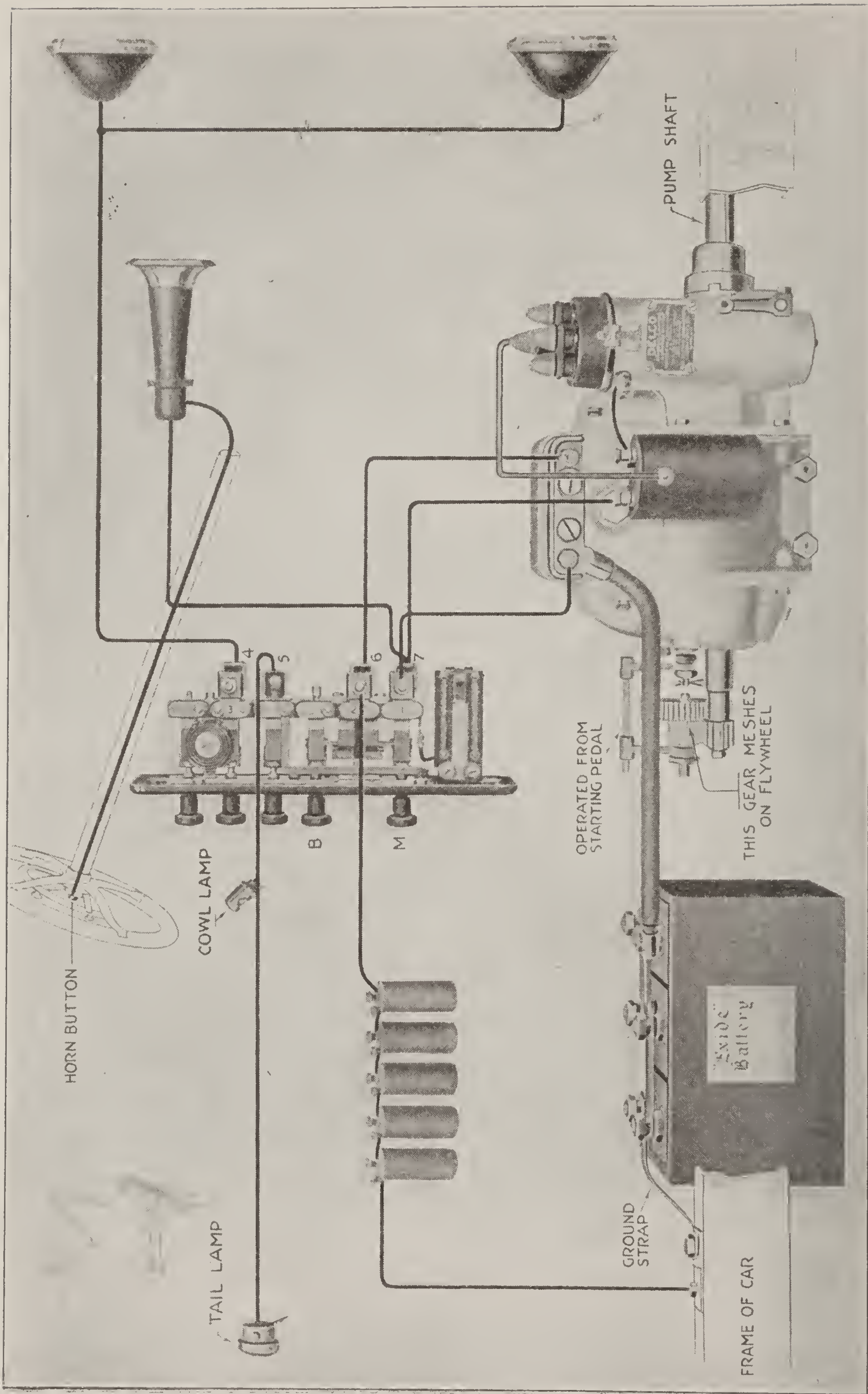


Fig. 145. Wiring of Delco Single-Unit, Single-Wire System
Courtesy of Dayton Electric Laboratories, Inc., Dayton, Ohio

METHODS OF REGULATION

Necessity for Control of Generator Output. In the section on Generator Principles, Part I, mention has been made of the fact that the speed with which the armature coils cut the lines of force of the magnetic field is the chief factor determining the e.m.f. and, in consequence, the current output of the generator. This, in connection with the heating effect of the current due to the resistance of the conductor, limits the amperage that the latter will carry safely. Beyond this point the insulation will take fire and, with a further increase in the temperature due to excessive current, the conductors themselves will fuse. With the extreme variation in speed presented by the operation of the automobile engine, the necessity for regulating the output of the generator will be apparent. There are almost as many methods of regulation as there are systems in use.

As explained in the section on Induction Sources of Ignition Current, Part II, the magneto is an electric generator that requires no current-controlling device, as the magnetic excitation of its fields is permanent. That is, barring gradual exhaustion through age, heat, and vibration, its magnetic field is constant, thus enabling it to generate a current at very low speeds; but the limitations of this type of field are such that electromagnetic fields are employed as in large direct-current generators. These fields depend for their excitation upon the current derived from the armature of the machine itself, and, as the amount developed by the latter increases in direct proportion to its speed, the fields become stronger as the speed increases and correspondingly more current is generated by the armature. As an automobile motor is driven at a great range of speeds, varying from 200 or 300 r.p.m. up to 2000 to 2500 r.p.m., or even higher, and the generator is usually geared in the ratio $1:1\frac{1}{2}$ so as to develop its rated output at the normal speed of the engine — its windings would be quickly burned out unless some provision were made to control its output.

Constant-Current Generator. Generators of the so-called constant-current type are frequently regulated by the winding alone. They are usually compound-wound, the series coil being so connected as to oppose the shunt. Assuming the coils to be in equally advantageous positions on the core, the limiting current then is one

which gives the same number of ampere turns to the series coil as to the shunt field. Thus, assuming 500 shunt turns in the winding and a shunt current of one ampere, there are 500 ampere turns in the shunt winding. If there are 25 turns in the series winding, the limiting current will be 20 amperes, 500 being the product of 20 by 25. With this winding 20 amperes will be the absolute limit of the current regardless of speed. As a matter of fact, it will be considerably lower than this in practice, owing to the armature reaction or counter e.m.f. generated.

Slipping-Clutch Type. As in every case speed is the direct cause of a rise in the voltage or increase in the current output, one of the methods available for regulating generators is that of mechanically governing the speed at which the generator runs. In the Gray

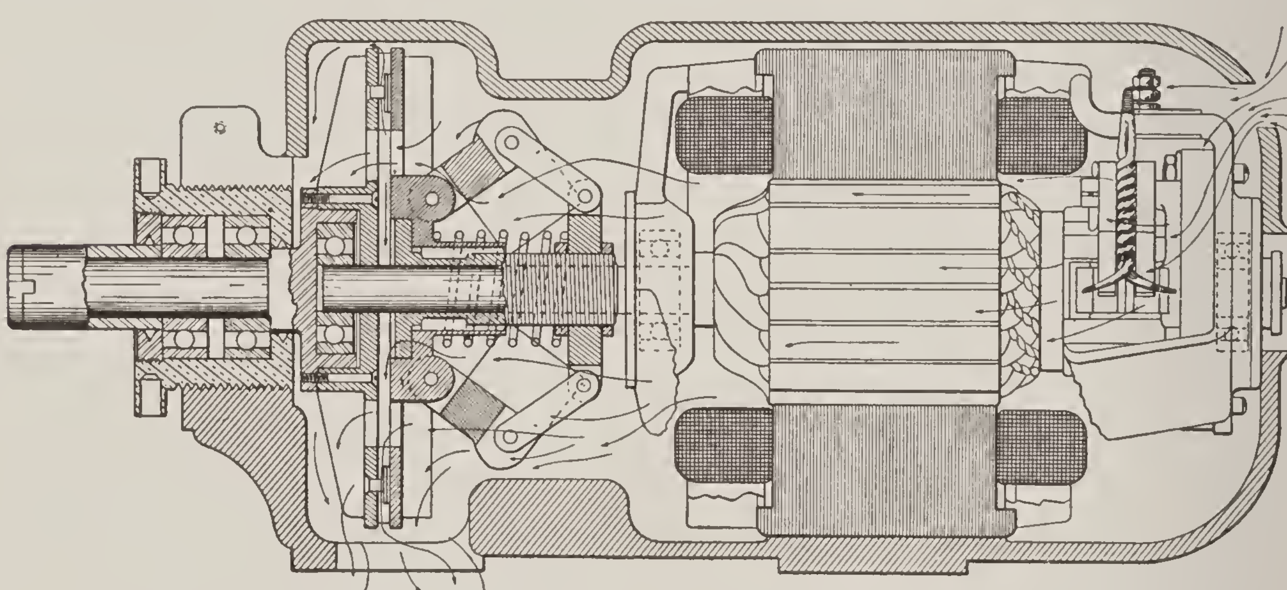


Fig. 146. Section of Gray and Davis Lighting Dynamo (Early Model, Now Obsolete)

and Davis, which is probably the most important representative of this type, a slipping clutch is used for this purpose. A centrifugal governor is employed, as shown in the sectional view, Fig. 146. The drive is through a two-plate friction clutch at the left, the plates of this clutch being normally held in engagement by a spring. The tension of this spring is controlled by the centrifugal governor to which it is attached at the right-hand end, and it may be adjusted to compensate for wear by means of the threaded shaft and nut. This clutch is set to slip at a certain torque and, as soon as the current value corresponding to this torque is attained, the clutch lets go, and the current cannot exceed this limit. Accordingly, one plate of the clutch (the driving side) runs faster than the driven side in proportion to the difference in the speed of the gasoline engine

and that at which the generator is designed to run, the *torque* on both sides of the clutch remaining the same regardless of this difference. Ventilation is provided to carry off the heat produced by the slipping clutch, the opening and the arrows shown in the illustration indicating the direction in which air is drawn into and expelled from

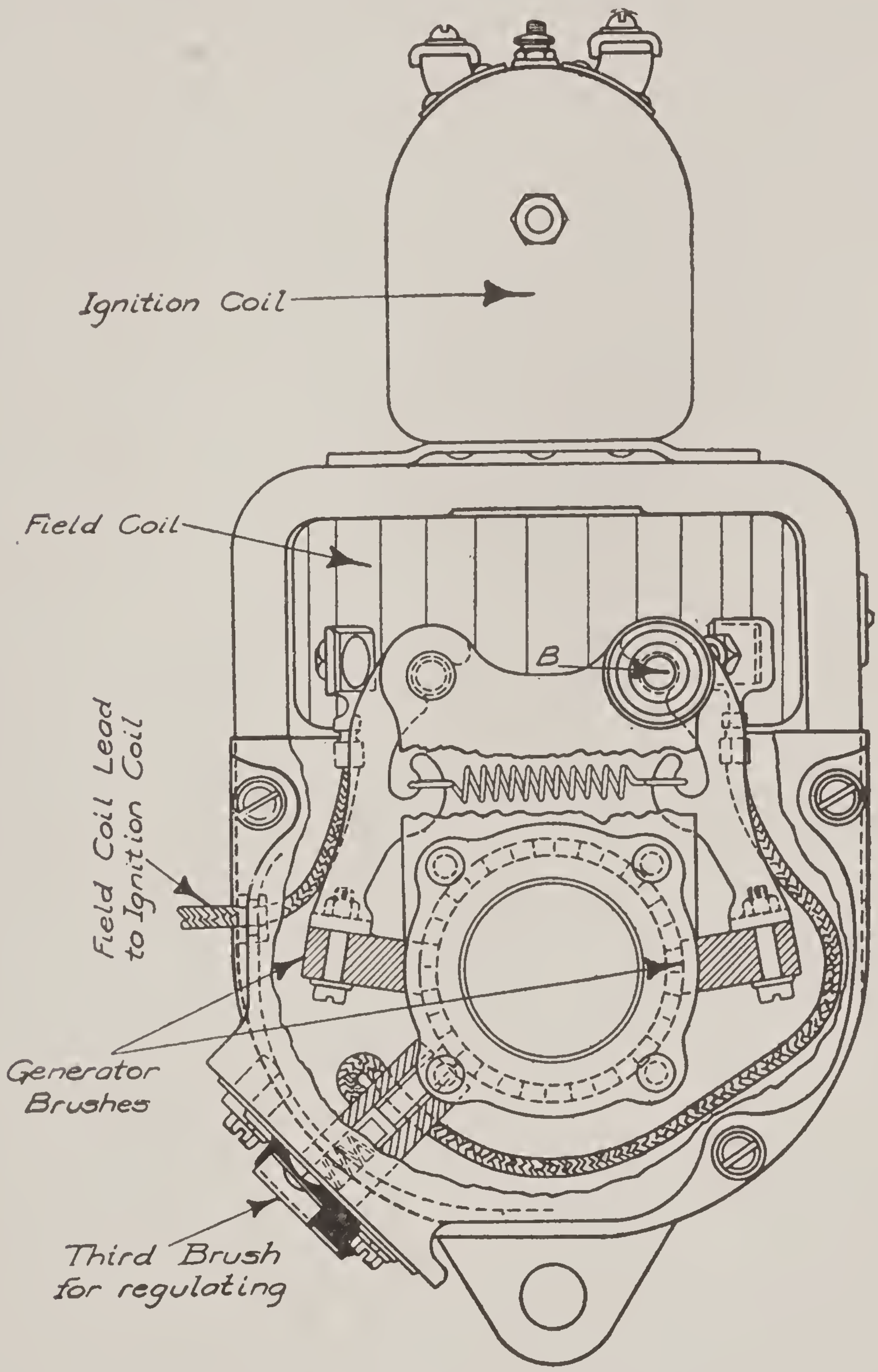


Fig. 147. Delco Third-Brush Method of Regulation

the housing. The generator is of the compound-wound type, and is known as a constant-speed constant-current dynamo. Regulation in this case is by purely mechanical means.

Inherently Controlled Generator. *Westinghouse Type.* A typical example of inherent regulation is represented by the Westinghouse

generator. (See Fig. 116, Part III.) When the generator is connected to the battery by the automatic cut-out, the current rises rapidly with the speed until a moderate value is attained. Current in excess of this value passes through a compound series winding, the polarity of which is opposite to that of the shunt winding of the fields. Consequently it acts to oppose the excitation set up in the field magnets by the latter above a certain point. This is known as a "bucking coil" and, while it permits the value of the current generated to increase slightly over the predetermined limit with a further increase in speed, it does not allow it to reach an excessive amount at any speed at which the car can be run. However, current for the lights does not pass through this reversed compound field winding and, when the lights are turned on, the output of the generator increases automatically to supply them. With the usual lamp equipment, this increase in generator capacity is sufficient to operate the lamps without any demand on the battery at ordinary running speeds. At low speeds the battery supplies a certain proportion of the lighting current, and when the engine is not running the battery takes care of the entire demand. When running at night, all current in excess of that required by the lights is utilized to charge the battery, which is thus said to "float" on the line. During the daytime, the entire output of the generator is absorbed in charging the battery.

Delco Third-brush Excitation. Another form of inherent regulation consists of the use of a special brush for taking the current from the armature for the purpose of exciting the field. An instance of this is found in the Delco two-unit system as built for the Oakland cars (1916 models). As the generator is a bipolar type, there are only two brushes for leading the current from the armature to the external circuit, so that the special regulating brush employed, as illustrated in Fig. 147, is commonly referred to as a "third brush". This applies only to this particular type, however, for if the generator were a multipolar type having four brushes, the regulating brush would then be a *fifth* brush. The Delco generator is shunt wound but differs from the standard machine of that type in that the shunt winding is connected to the third brush which bears on the commutator between the other brushes. This method has the advantage of providing a strong shunt field at low speeds so that the generator commences charging while the car is still traveling at a very moder-

ate pace. As the speed increases the voltage applied to the shunt field is decreased, although the total voltage between the main brushes may have increased. This weakens the field and prevents the output of the generator from increasing with the increased speed. At the higher speeds it acts somewhat similarly to the bucking coil previously described, in that it still further weakens the field and causes the generator output to decrease.

Bosch-Rushmore Type. In the Bosch-Rushmore generator, inherent regulation is obtained with a bucking-coil winding used in conjunction with a so-called "ballast" coil, which automatically cuts the bucking coil in or out of the circuit according to its resistance, Fig. 148. Advantage is taken of the fact that the electrical resistance of iron increases enormously after its temperature rises beyond a certain point. This ballast coil accordingly consists of a few turns of fine iron wire on a fluted porcelain rod. The bucking coil, the effect of which is to reduce the field excitation of the dynamo, is connected as a shunt across the iron ballast coil, as shown in Fig. 148. Its resistance is considerably greater than that of the ballast coil when the latter is cold or only warm, so that at low engine speeds practically all of the current generated passes directly to the battery and lamps and the generator acts as a single-shunt dynamo. However, the resistance of the iron wire increases at a constant rate up to about 10 amperes, after which it mounts very suddenly, preventing the passage of any excess current, which, accordingly, must go through the bucking coil. Thus the latter only comes into action at high speeds, so that the output of the dynamo may be adjusted to any value within its capacity simply by employing an iron wire of suitable diameter in the ballast coil.

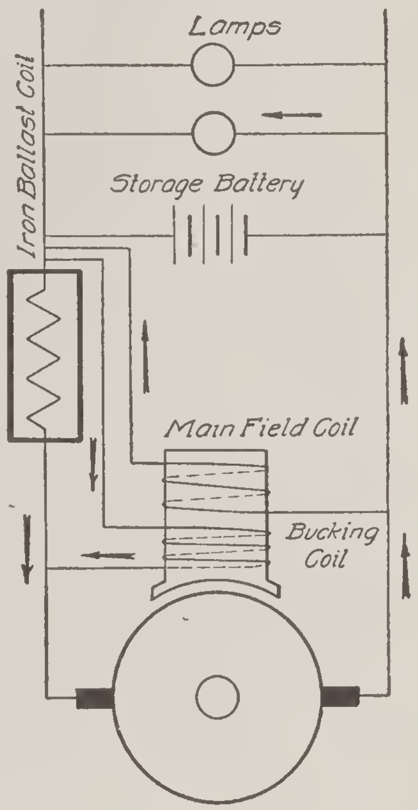


Fig. 148. Connections Bosch-Rushmore Generator

Independent Controllers. The Ward-Leonard controller (constant-current), Fig. 149, is typical of the external or independent controlling devices. In principle, this is the same as the Splitdorf and many others, the chief distinctions between the types usually being found in their construction. Referring to Fig. 149, the coil F,

on the magnet core G, carries the armature current, and when the latter exceeds a certain value—the standard being generally about 10 amperes—the core becomes sufficiently magnetized to attract the finger H. This separates the contacts EE', and the resistance M is inserted in the field circuit and weakens it. The current then decreases, but when it drops to about 9 amperes, the pull of the magnet is not sufficient to overcome the tension of the spring J, and the contacts EE' come together again. In actual operation, the finger H is kept vibrating at a rapid rate. As a result, the dynamo cannot charge the battery at a rate in excess of 10 amperes, regardless of the speed. At all car speeds above a predetermined limit, usually 15 miles per hour in practice, the dynamo generates a substantially constant current. The regulating device shown at the left of the figure is the automatic cut-out to break the circuit between the battery and the dynamo when the speed of the latter falls below a point at which it is no longer capable of producing the necessary voltage for charging. This is referred to later.

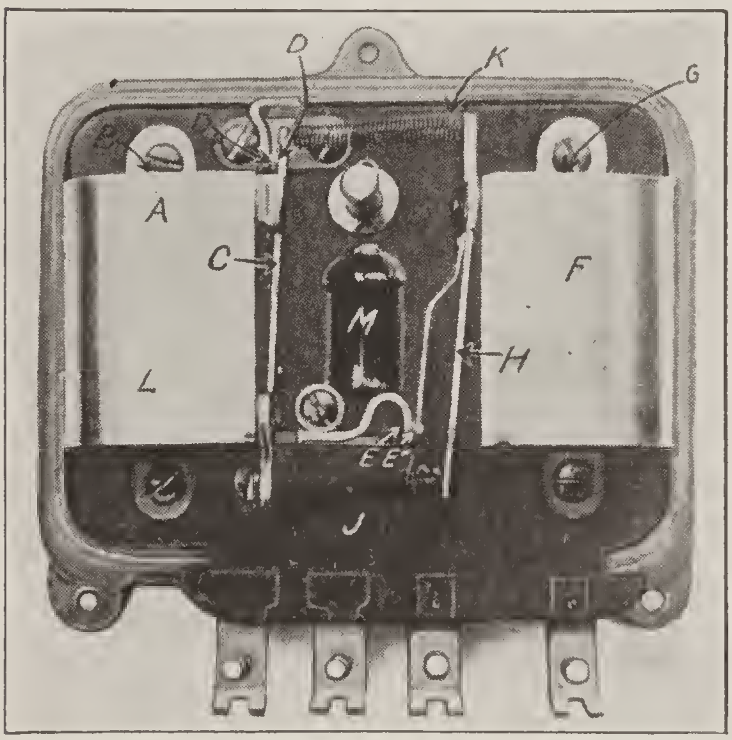


Fig. 149. Ward-Leonard Current Controller and Automatic Cut-Out

All external regulators are not of the constant-current type, however, as some limit the voltage.

Constant-Potential Generators. There is probably a greater variation in the methods employed to control this type than in the constant-current type. This difference is in the method rather than the principle employed, as the majority of such regulating devices act to control the potential by automatically inserting extra resistance in the field circuit or in series with the armature. Quite a number of generators of this type are fitted with a vibrating contact operated by a magnet in much the same manner as a vibrating ignition coil is actuated. The device is either built as a separate unit or is incorporated as in the Splitdorf earlier models.

"Built-In" Regulator Type. In the Splitdorf generator, where the armature is supported by the usual ball bearings, the field poles have extensions which carry windings for the purpose of aiding in the regulation. Extending across these polar projections is a "keeper" (an unwound armature) held by a spring, and in connection with this keeper is a second spring for adjusting the tension of the first spring. The circuit of the battery is closed by the keeper being drawn toward the pole tips under the influence of their magnetism when the machine is running. The coils around these polar extensions are wired in series with the armature of the generator. When the current in the armature reaches a certain predetermined value,

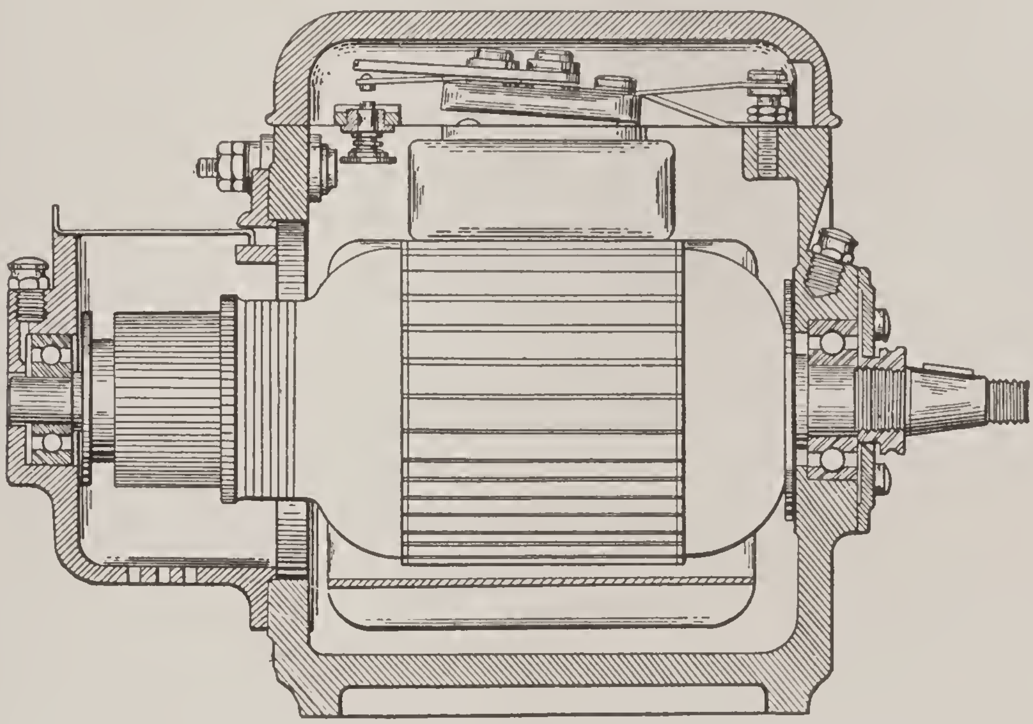


Fig. 150. Section of Splitdorf Generator Showing Controller

the keeper is drawn all the way down and an auxiliary contact is opened which cuts a resistance into the shunt winding of the fields, and thus reduces the magnetic flux due to their action. This, together with the differential action of the series coils on the polar extensions, reduces the magnetic flux through the armature to such a value that the current to the battery does not increase beyond a certain value, no matter how fast the armature is turned. A sectional view of the machine illustrating the details mentioned is shown by Fig. 150. As the speed diminishes the reverse operation of the controller takes place. This generator is driven at twice the crankshaft speed of the motor, and when installed on a car with 34-inch wheels and geared at 3.7 to 1 on direct drive, begins to

charge the battery at 7 miles per hour. The high-speed control acts when the car is running between 35 and 40 miles per hour.

External Regulator Type. The Adlake generator is of the constant-potential type governed by an external regulating device, the details of which are shown in Fig. 151. While termed a "regulator", it also incorporates the automatic battery cut-out and the fuses on the same base. This device has been in use on Pullman railroad cars for a number of years, the dynamo in that case being driven from one of the axles of the car. The principle is that of inserting added resistance in the field circuit of the dynamo as its output increases in order to maintain the voltage practically constant. Its operation is made clear by reference to the diagram, Fig. 152. G is a solenoid or hollow electromagnet, in the opening of which the plunger K may move vertically. The weight of K is counterbalanced by N, a small piston moving in the cylinder O, small shot being put in this piston until both are in equilibrium. They are connected by a chain passing over M. An arm F, attached to M, carries a movable contact designed to make connection with the various contacts of the rheostat C, thus putting in circuit a greater or less number of the German-silver-wire resistance coils composing it. These coils are connected in series with the field of the dynamo, which is a plain shunt-wound machine.

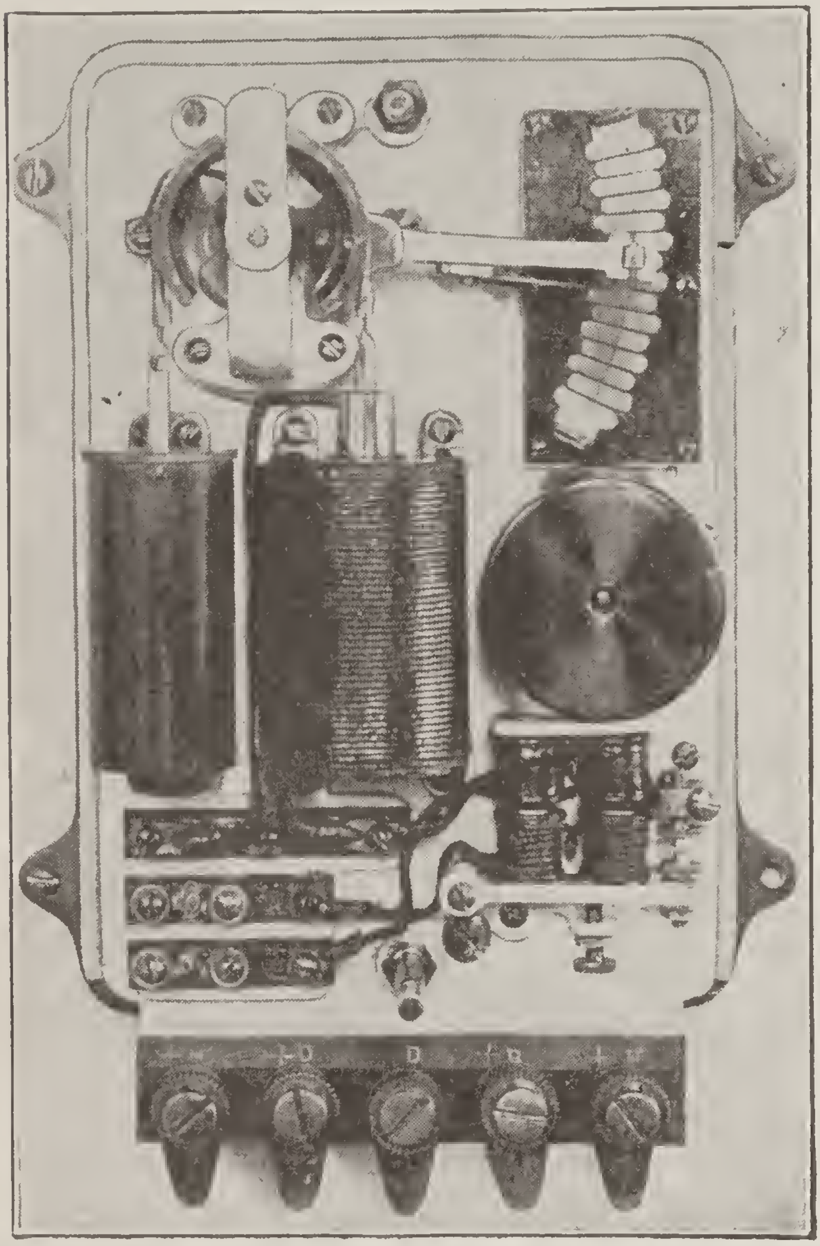


Fig. 151. Adlake "Regulator"

In explanation of the wiring diagram for the Adlake regulator, Fig. 152, start at terminal A of the generator; the current flows to A_1 on the regulator and thence to the fuse block a. It is here the shunt-field circuit begins. The field current flows from a through b to the rheostat terminal c and through a number of the sections of the latter, depending upon the position of the arm F, through this arm and back through d to the fuse block e, thence through

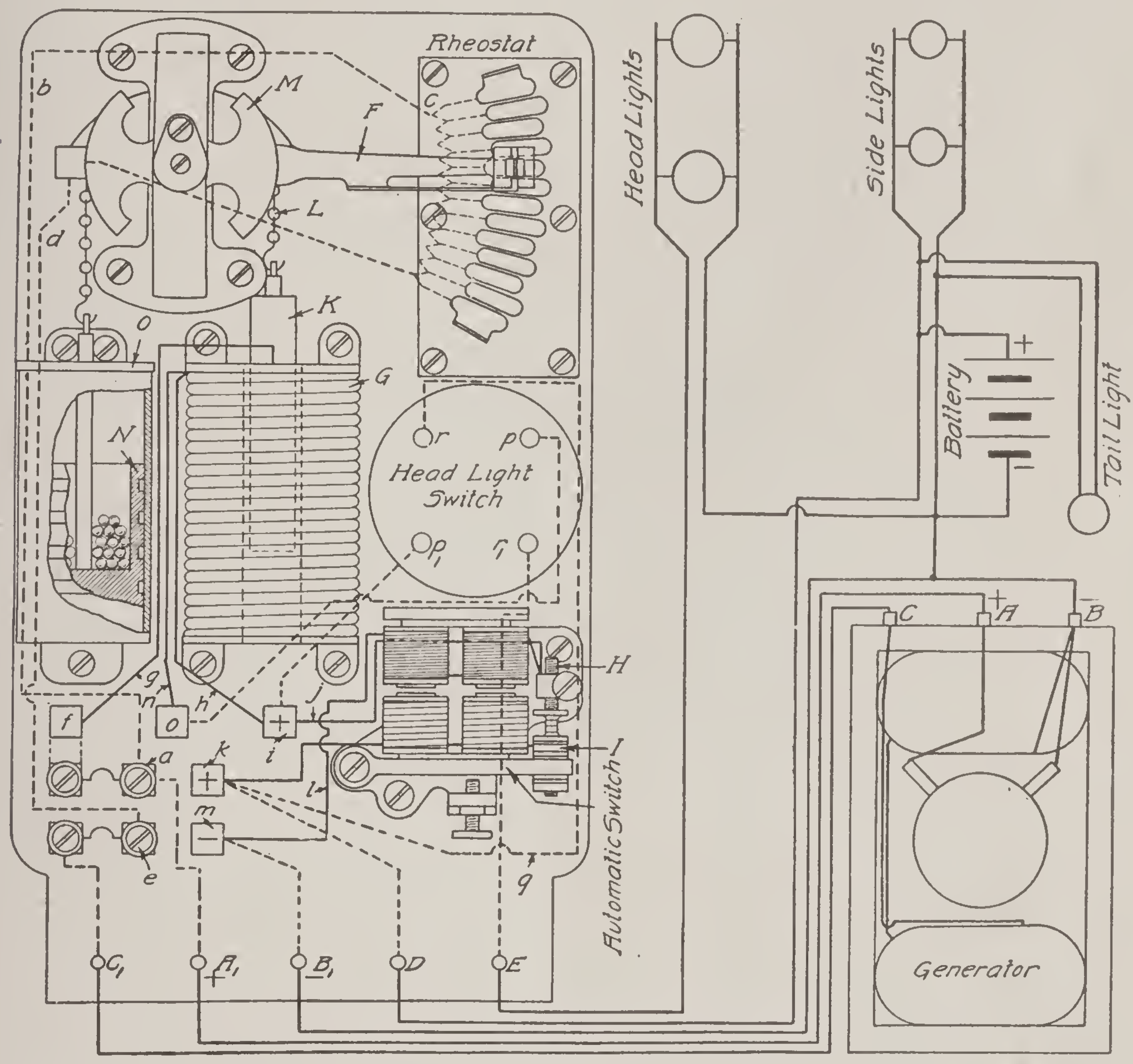


Fig. 152. Connections for Adlake "Regulator" (*Horseless Age*)

the fuse to terminal C_1 and from there to the terminal C of the generator, thence through the two shunt-field coils and back to the negative terminal B of the generator. From B the current flows through the generator armature back to A, thus completing the circuit. There being only one field winding, the current always takes the same path, except that it has to flow through more or less of the resistance sections of the rheostat, of which there are fifteen. The path of the main or charging current is from the fuse block a to the connector

f, and through *g* into the solenoid coil *G*. It leaves this coil through *h* and flows to the contact block *i*, which connects by the wire *j* with the stationary contact screw *H* of the automatic battery switch. When the latter is closed for charging, the current flows across to the movable contact point *I* of the switch, and thence through the two lower or series coils of the automatic switch to the connector *K*. From this it flows to the terminal *D* of the regulator, which is directly connected with the positive terminal of the battery, and the current, after flowing through the battery, returns to the negative terminal *B* of the generator through connections clearly indicated.

There are a number of variations in the methods of regulation employed, as well as some that are not given in the foregoing résumé. These are explained in detail in connection with the descriptions of the different systems.

PROTECTIVE DEVICES

Various Forms. When fully charged, the storage battery holds in chemical form the equivalent of two or more horsepower, i.e., 40 to 160 amperes at 6, 12, or 24 volts, according to the system employed and the capacity of the battery furnished. An accidental ground or short circuit in the wiring system would release all of this energy in a flash to the great detriment of the battery itself as well as to any of the apparatus or parts of the car that happened to be included in its path or circuit. To guard against damage from such a cause, various forms of protective devices are employed, and the different systems vary as much in this respect as they do in others. In some instances, a circuit breaker is depended upon to take care of all the circuits. In others, further protection is afforded by the employment of fuses, as well as a circuit breaker. Fuses very generally are employed to protect the lighting circuits as well as some of the other circuits.

Automatic Battery Cut-Out. It will be evident that, if the storage battery were at all times in direct connection with the generator, it would immediately discharge through the latter as soon as the driving speed fell to a point where the dynamo was no longer producing sufficient voltage to charge the battery. If the generator were free to run instead of being positively connected to the engine, it would become "motorized" and operate as an electric motor on

the battery current. As it is so connected, the battery current would simply burn out its windings, owing to the low resistance of the latter at low speeds. Consequently it is necessary to insert an automatic switch in the circuit in order to connect the battery with the generator when the speed of the latter reaches a certain point, and to disconnect it as soon as it falls below that value. Such switches are termed automatic cut-outs or "reverse-current relays." In single-unit systems, such as the Dyneto, no battery cut-out is employed. A single hand-operated switch controls both the ignition and the generator-battery circuits, so that this switch is left closed as long as the engine is running. Should the engine stall, the battery current automatically "motorizes" the generator and re-starts the

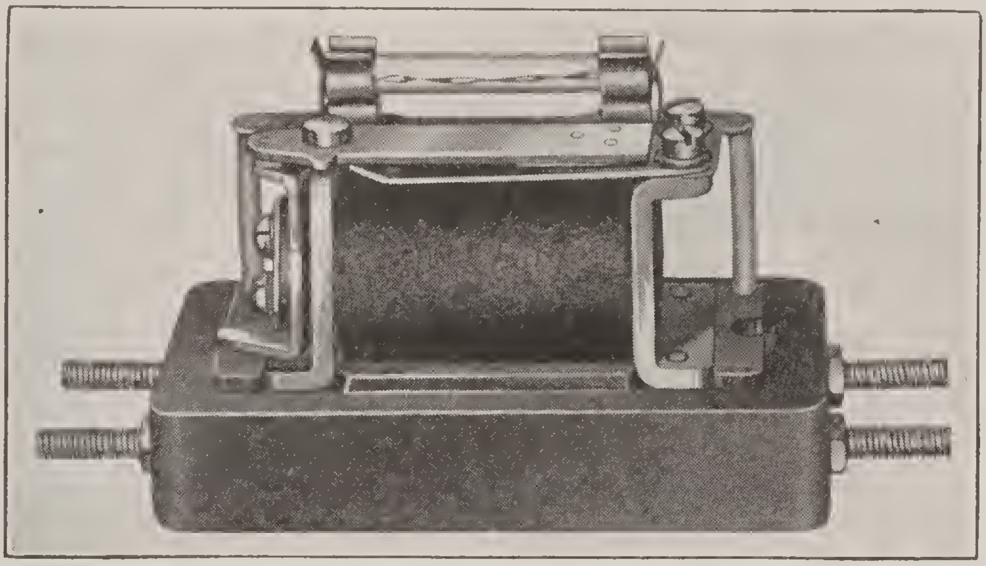


Fig. 153. Remy Reverse-Current Relay

engine. With such systems the engine must not idle slowly and the starting switch must not be left closed after the engine has stopped.

Ward-Leonard Type. The Ward-Leonard, Fig. 149, is typical in that it clearly illustrates the principles upon which most of these devices are based, though their construction varies widely, as will be noted by Fig. 153. The switch mechanism is shown at the left of Fig. 149. In this device A is the coil, B the magnet core, C the movable arm, and DD' the contacts. The dynamo generates sufficient voltage at a car speed of approximately 7 miles per hour to attract C and hold it in position, closing the battery circuit through DD' and charging at any speed above starting speed.

Adlake Type. In Fig. 151, the automatic cut-out switch is seen at the lower right-hand corner of the panel. This differs from the usual types in that it has two shunt and two series electromagnets.

The closing of the switch is effected by the two upper or shunt coils. The current for these coils follows the path of the main charging current as far as the stationary contact screw *H* of the switch, from which a connection leads to the fine windings of the shunt coils; after passing through these coils, it flows through the wire *l* to the connector *m*, which is connected to the terminal B_1. Consequently, as soon as the generator begins to pick up, current flows through the two upper or shunt coils of the switch, and when the magnetism due to this current becomes strong enough the switch closes. Current then flows into the battery for charging, first passing through the two lower or series coils, which greatly increase the pressure at the contact points as long as the charging current is flowing, and insuring a positive interruption of the current when the generator voltage drops below that of the battery. A powerful actuating force is thus obtained with very small magnets.

Circuit Breaker. Circuit breaker, as employed in this connection, must not be confused with "battery cut-out". The cut-out is literally a circuit breaker and is referred to as such by some manufacturers in their instructions, but in electric terminology, as employed in everyday use, the circuit breaker and the cut-out are entirely different things. A circuit breaker is designed to operate only when a current considerably in excess of that for which its circuit is intended passes through it. Whether a protective device is a cut-out or a circuit breaker may be determined by the circuit in which it is placed. The cut-out is never employed in any other circuit than that of the generator and battery. A detailed explanation of the circuit breaker is given in connection with the Delco system.

STANDARDIZATION

Voltage Standards. Weight reduction is a problem of the greatest importance on the automobile and as energy in the form of a lead-plate storage battery is very heavy, the size of the latter is very closely limited. Power, however, depends not so much upon the amount of energy available as it does upon the pressure at which it can be applied. Thus, by doubling the voltage of a storage battery, the capacity needed can be reduced correspondingly. Where only three cells are employed, they must be very much larger than when six are used, and the cells of the latter must be correspond-

ingly larger than those of a 9-cell or a 12-cell battery. While there are a few adherents of the higher voltage battery represented by the systems in use today, the majority favor the 6-volt standard.

Variation by Manufacturers. A final difference to be noted is that systems of totally different characteristics are turned out by the same manufacturer. Automobile motors are still a long way from reaching a degree of standardization that permits them to be classified according to horsepower, dimensions, number of cylinders, or any other easily applied standard so far as their requirements from an electrical point of view are concerned. The manufacturer of electrical apparatus accordingly designs a starting and lighting system to meet the requirements of a certain motor and it will give the most efficient service only when applied to that particular motor. This accounts for the major part of the great variation in electrical systems that exists and particularly for the difference between the equipment of the successive models of the same make of automobile. For that reason, it must never be concluded that a Delco, a Gray & Davis, a Bijur, a Wagner, or any other starting and lighting system is always the same on whatever car it may be found. Automobile manufacturers alter the characteristics of their motors from year to year, and the manufacturer of electrical apparatus not only keeps pace with this by redesigning his system to correspond but also introduces various improvements suggested by experience and the development of the art. In consequence, it would be manifestly impossible to attempt to outline in detail the features of every starting and lighting system to be found on all the cars now running, thousands of which are three to five years old. The following analysis accordingly covers only those of more recent manufacture, but by a study of these it will be easy to become familiar with the general characteristics of all, and to note at a glance where improvements have been made from year to year.

STARTING MOTORS

Speaking broadly, there are three classes of starting devices worthy of mention, viz, the mechanical or spring-actuated devices; the compressed fluid devices; and the electrical starters. While still employed to some extent abroad, compressed air and similar devices

are now only of historical interest here as they have been displaced almost entirely by the electric starter.

Modern Electric Starting System Anticipated Sixteen Years. Although it has only come into general use within the last few years, the possibilities of the electric starter on the automobile were foreseen at an early day. Those to whom it has appeared as a novel development of very recent adoption will doubtless be surprised to learn that a car embodying many of the features of present-day electrical systems was built in 1896. Indeed, the following description of it might well apply to the present U.S.L. system, which employs the flywheel type of dynamotor. The machine in question was a Diehl specially wound Gramme-ring type designed to operate at 12 volts. The armature, which weighed 111 pounds, served as the flywheel of a two-cylinder horizontal opposed 6- by 7-inch motor. The system was described as follows:

"The flywheel is constructed as a dynamo, which by rotary motion charges a storage battery carried in the vehicle. At the time of starting the carriage, the motorman turns a switch which discharges the storage battery through the dynamo, converting it for a few seconds into a motor, which, being upon the main crankshaft, gives rotation and does away with the necessity of starting the flywheel by hand. After the motor gives the crankshaft a few turns, the cylinders take up their work and the battery is disconnected from the dynamo, which then acts as a flywheel.

"The flywheel dynamo furnishes the current for the induction coil of the sparking mechanism as well as for the electric lamps at night, thus doing away with the necessity of going to a charging station. Attached to the crankshaft is a device for changing the point of ignition of the spark in the combustion chamber, perfectly controlling the point of ignition, acting as a 'lead' and allowing the motors to be operated at a variable speed, according to the work done."

From this it will be seen that as early as the spring of 1896, the present complete electrical equipment of the automobile, including ignition with automatic spark advance, electric lighting and starting, was fully worked out and applied to an actual machine. It was not until sixteen years later that what had been anticipated at such an early day in the history of the automobile became accepted

practice in all the essential points mentioned. In addition, the machine in question was provided with a magnetic clutch which automatically connected and disconnected the engine every time the gear-shifting lever was moved, thus anticipating the present-day electromagnetically operated gearbox.

Requirements in Design. The conditions in applying an electric starting motor to the gasoline engine bear no relation whatever to those of the lighting dynamo, so that the problem is not, as might be supposed, merely a question of reversing the functions of a single unit of the same characteristics. Practically the only requirements of the dynamo that differ from standard practice in other fields are that it shall commence to generate at a comparatively low (car) speed and that its output shall not exceed a safe limit no matter how high the speed at which it is turned over. The problem of the starting motor, on the other hand, involves conditions which have not had to be met in the application of electric motors to other forms of service. For example, a very high torque must be developed to overcome the inertia of the load, and the latter takes the form of intermittent rather than of steady resistance to the driving effort, owing to the alternate compression and expansion in the motor cylinders. The trolley car might be cited as a parallel to the heavy starting torque required, but the intermittent load, as well as the highly important limitations of weight, restricted current supply, voltage, and space considerations, are entirely lacking.

In the last analysis, the electric starter is nothing more nor less than a storage-battery starter, since most of its limitations are centered in that most important essential. The matters of driving mechanism, starting speed, and other equally important details can all be based on what is either accepted practice of long standing in other fields, or on the knowledge of starting requirements gained in the years of experience in applying manual effort to that end, but the storage battery will always constitute the chief limiting factor. This should be borne in mind in considering the forms that various solutions of the problem have taken, and, above all, it must be given first consideration in the successful maintenance of any electric starting system, as the majority of troubles met with have their origin in the neglect of the battery.

Wide Variation in Starting Speeds. In view of the long experience in hand-cranking the motor, it would seem that a definite basis for the starting speed would be an easy thing to establish, but this has not been the case. If "motor" briefly summed up in one word all of the varying characteristics to be found in the great variety of engine designs to which starters must be applied, this might have been easier of accomplishment. What suffices to start one make is, however, frequently found to be totally inadequate for others of apparently identical characteristics, so that in the different makes of starters this essential is found to range all the way from 25 r.p.m. to 200 r.p.m. or over. The necessary speed is largely influenced by the carburetion, as with the stand-by battery ignition almost universally provided, dependence need not be placed on the magneto to start; but to draw a mixture from the carbureter of a cold engine calls for speeds in excess of the lower limit of the range given. The most severe service demanded of the starter and the time when it is most needed are coincident, i.e., in winter use, and the equipment must naturally be designed to meet successfully the most unfavorable conditions. Even with starting speeds of 100 r.p.m. or over, it has been found impossible to start some motors without resort to priming. Some idea of the great variation in the speeds adopted will be evident from the fact that the North East starter, as originally built, was designed to turn the Marmon six-cylinder motor over at only 25 r.p.m.; the Hartford on a similar motor at 70 r.p.m.; the Westinghouse, 80 r.p.m.; Delco, 150 to 175, and the U.S.L. at 200 or over. These speeds are not invariable by any means, as in every case the starting equipment is designed particularly for the motor to which it is to be applied, and will run at different speeds in accordance with the requirements of the engine on which it is installed.

Practice Becoming Standardized. So far as practice may be said to have become standardized at the present writing, speeds of 80 to 100 r.p.m. represent a close approach to the average. One of the reasons for making the speed so much higher than could be effected by hand-cranking is the slowing down of the motor as the pistons reach the maximum compression point in the cylinders, while another is the necessity for drawing a charge of fuel from the carbureter under the most adverse conditions so that starting shall always be accomplished without resort to priming.

Voltage. When an engine has been standing idle for some time at a temperature well below the freezing point, the lubricating oil becomes extremely viscous and the current required for starting at a low voltage is very high. The 6-volt standard inherited from dry-cell-ignition days accordingly appeared to be entirely too low at the outset, and several systems employing 12- and 24-volt batteries were developed. The higher efficiency of the latter in starting is opposed by certain disadvantages inherent in this type of installation. Experience has shown, however, that with proper installation and maintenance the 6-volt system affords advantages which more than offset any increase of efficiency derived from the use of a higher voltage, and the majority of well-known starting systems are now designed to operate on a potential of 6 volts.

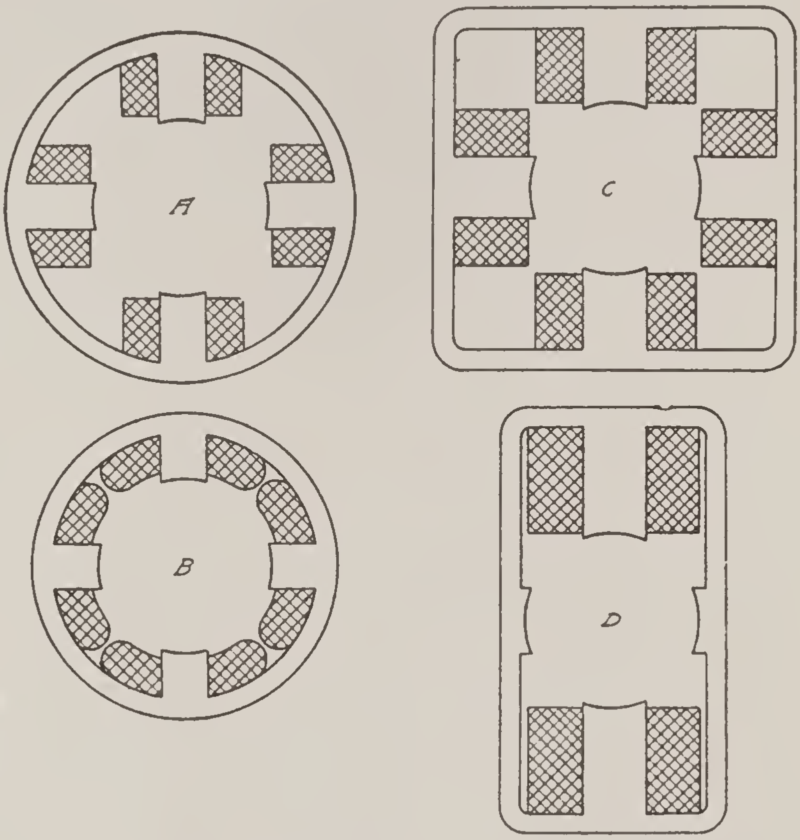


Fig. 154. Cross-Sections Typical Electric Starting Motor
Courtesy The Automobile, New York City

Motor Windings and Poles. The necessity for developing a powerful torque at low speeds naturally calls for a series-wound motor, such as is employed in street-railway and electric-automobile service, and all starting motors are of this type. Motors built to operate at such a low voltage being new to the electrical designer there is more variation in the form and size of starting motors than exists in power units running on current at commercial voltages.

Standard Designs. Briefly stated, the electrical requirements demand a concentrated and correctly proportioned mass of iron and copper in the minimum space. The cross-sections, Fig. 154, show how these requirements have been met in various instances. As the motor is only required to operate for very short periods, both the conductors and insulation can be kept down in size as compared with a motor designed to run constantly under heavy load.

Commercial Forms. The problem is to provide for a certain number of ampere turns around the poles and a magnetic circuit through the latter, as well as steel housing or frame of sufficient cross-section to carry the required degree of magnetization with the

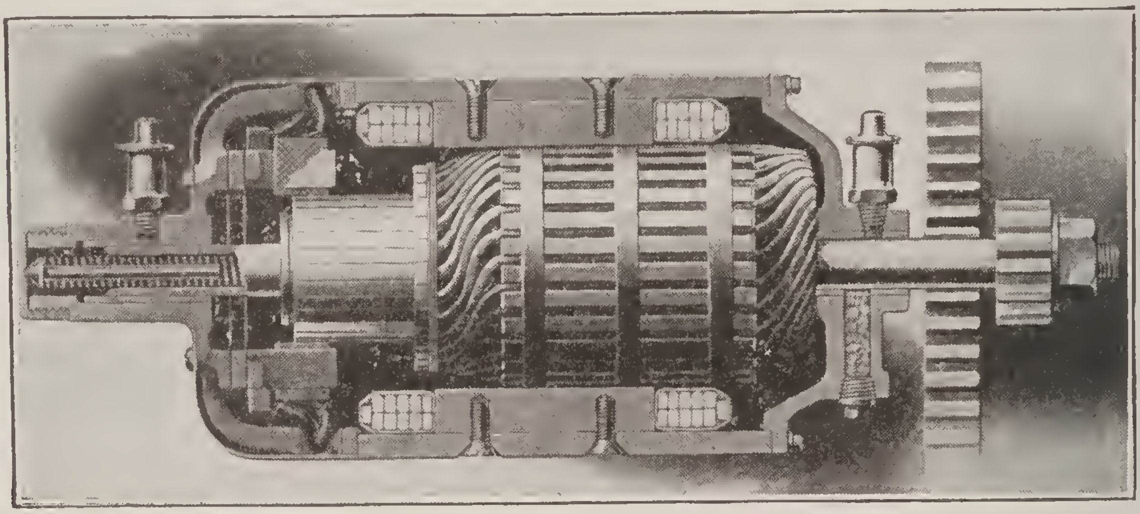


Fig. 155. Section of Bosch-Rushmore Starting Motor

shortest magnetic circuit. Consequently, shallow windings with long flat pole pieces are more efficient than the reverse of this form, particularly as air space in the magnetic field lessens its intensity and calls for a heavier winding to magnetize the extra weight of metal to the same degree. Hence, the type represented by *B*, Fig. 154, is the most efficient, in theory at least, of the four forms illustrated.

Whether the windings be placed on two poles or on four poles is something that each designer decides according to his own preference in the matter. The Bosch-Rushmore starting motor, Fig. 155,

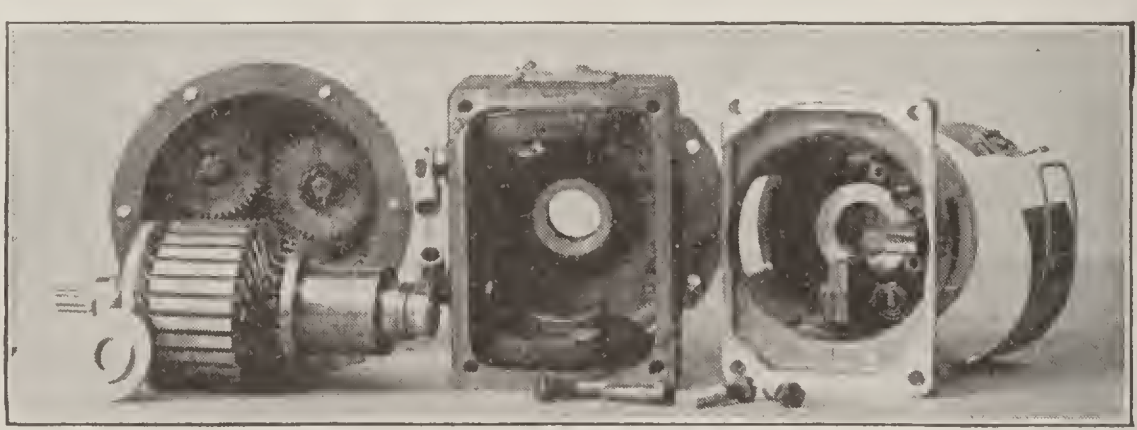


Fig. 156. Westinghouse Starting Motor

exemplifies type *B* referred to above, except that it is bipolar. Windings and pole pieces of the same type are shown in the Westinghouse starting motor, Fig. 156, this being patterned after form *D* in Fig. 154, though it is of somewhat broader section. The auxiliary

unwound pole pieces at the sides do not show very clearly in the illustration; they are of substantially the same form, though con-

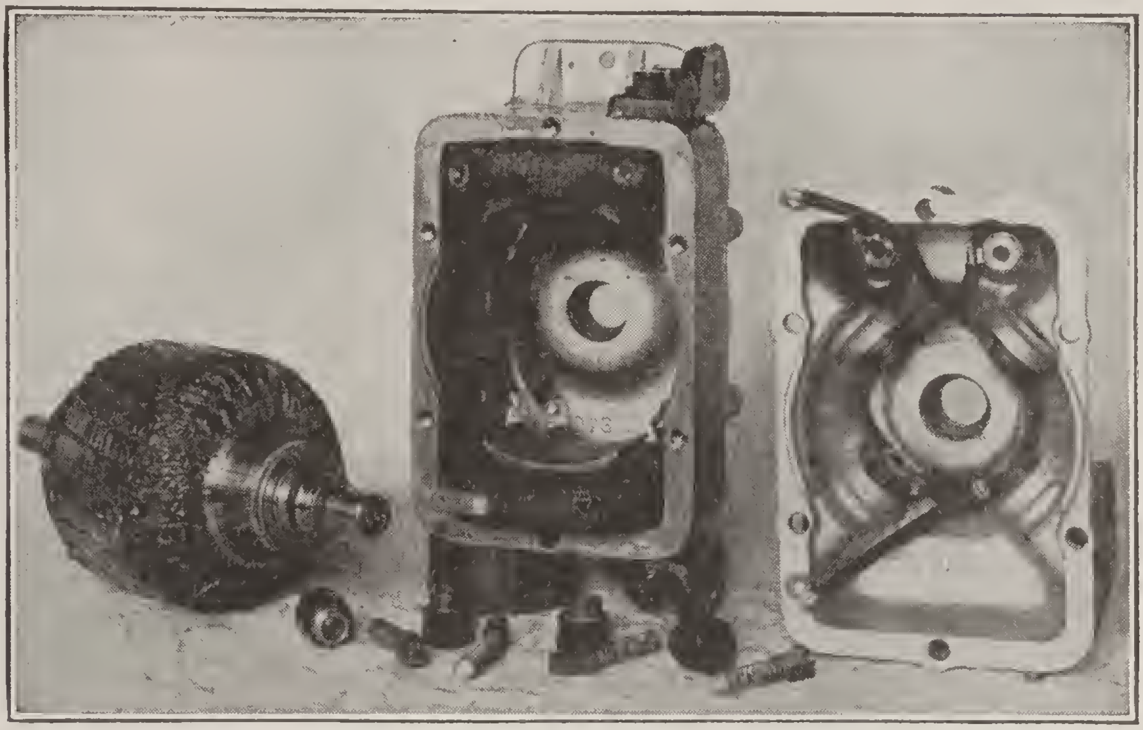


Fig. 157. Bipolar Type Westinghouse Starting Motor

siderably wider than those illustrated in the section in question. For a more restricted space a straight rectangular bipolar type is made, Fig. 157. From the standpoint of both electrical efficiency and space considerations, practice favors the cylindrical rather than the rectangular form.

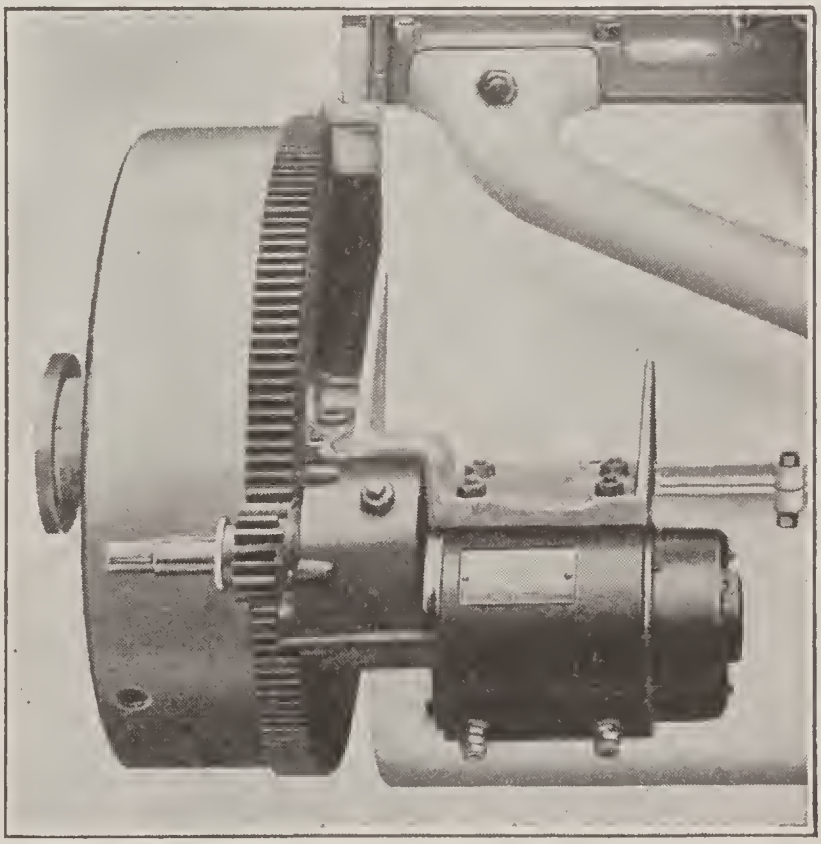


Fig. 158. Double-Reducing Gear Type Installation, Wagner Starting Motor

TRANSMISSION AND REGULATION DEVICES

Installation. As the driving requirements of starting with such a small power unit as space and weight limitations make necessary call for a high-speed motor and a high gear ratio to effect the necessary speed reduction, the mounting of the starting motor is totally

different from that of the lighting dynamo. The electric motor runs at 1800 to 3000 r.p.m. or over, according to its design, while, as already mentioned, the engine starting speeds usually average 80 to 100 r.p.m. The great speed reduction required is effected in the majority of instances by utilizing the flywheel as the driven gear, a gear being bolted to it, as shown in Fig. 158, which illustrates the application of a Wagner starter to the Moline-Knight 50 horsepower four-cylinder motor. Or the gear teeth may be cut directly in the periphery of the flywheel itself, as shown by the Delco single-unit

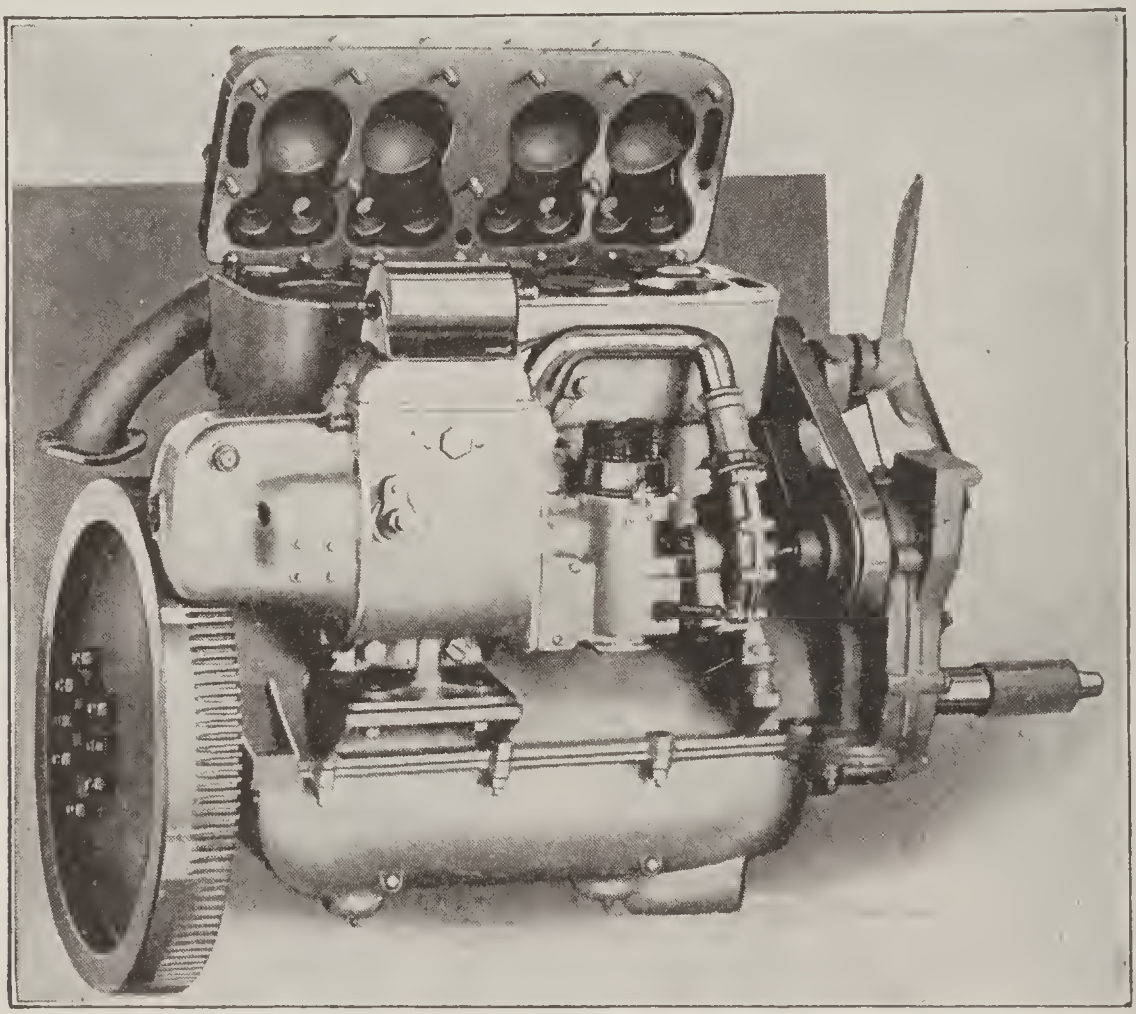


Fig. 159. Mounting of Delco Single-Unit System

system mounted on a Cartercar four-cylinder engine, Fig. 159. In either case, this does not afford sufficient reduction in the speed, and an intermediate set of gears is necessary in installations such as those illustrated. This gearing may be mounted as an attachment to the engine or combined with the starting motor, as shown in Fig. 160, showing a Ward-Leonard starting motor with enclosed gearing. In some instances, a planetary type of gear is employed, an example of which is found in one type of the Westinghouse starting motors, Fig. 161, the gearbox being incorporated in the motor housing and

the pinion driving direct. In view of the large reduction available in a planetary gear, a starting motor of this type may be employed to drive through a camshaft or similar location. Planetary gears are also utilized on some of the single-unit systems, such as the Northeast, the gear ratio used being something like 40 to 1 when the dynamotor is used for starting and 1 to $1\frac{1}{2}$ or 2 when running as a generator, Fig. 162. Silent chains are made use of in some cases, but this is done more frequently where a starting and lighting system is applied to an old car rather than to one for which it has been especially designed. Where the starting motor is of a comparatively low-speed type, the single reduction between the motor pinion and the flywheel suffices. Fig. 163 shows a Ward-Leonard starting

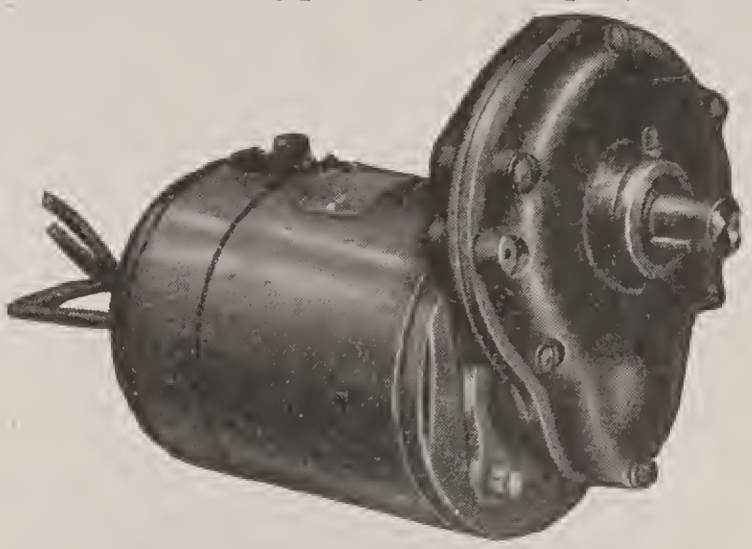


Fig. 160. Reducing Gearing Attached to Ward-Leonard Starting Motor

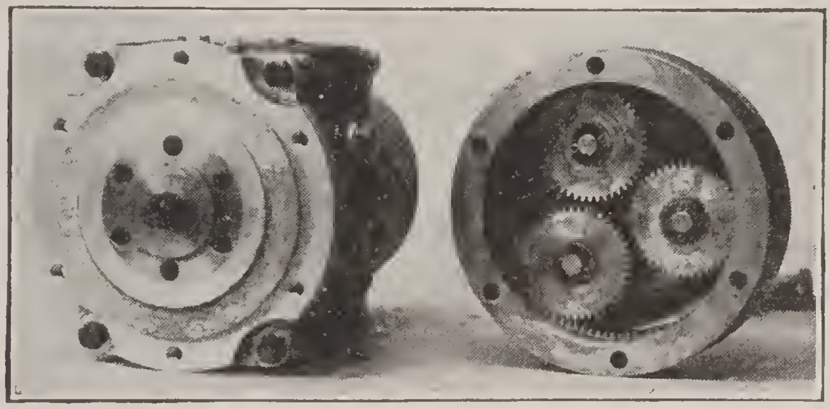


Fig. 161. Westinghouse Starting Motor with Planetary Reduction Gear

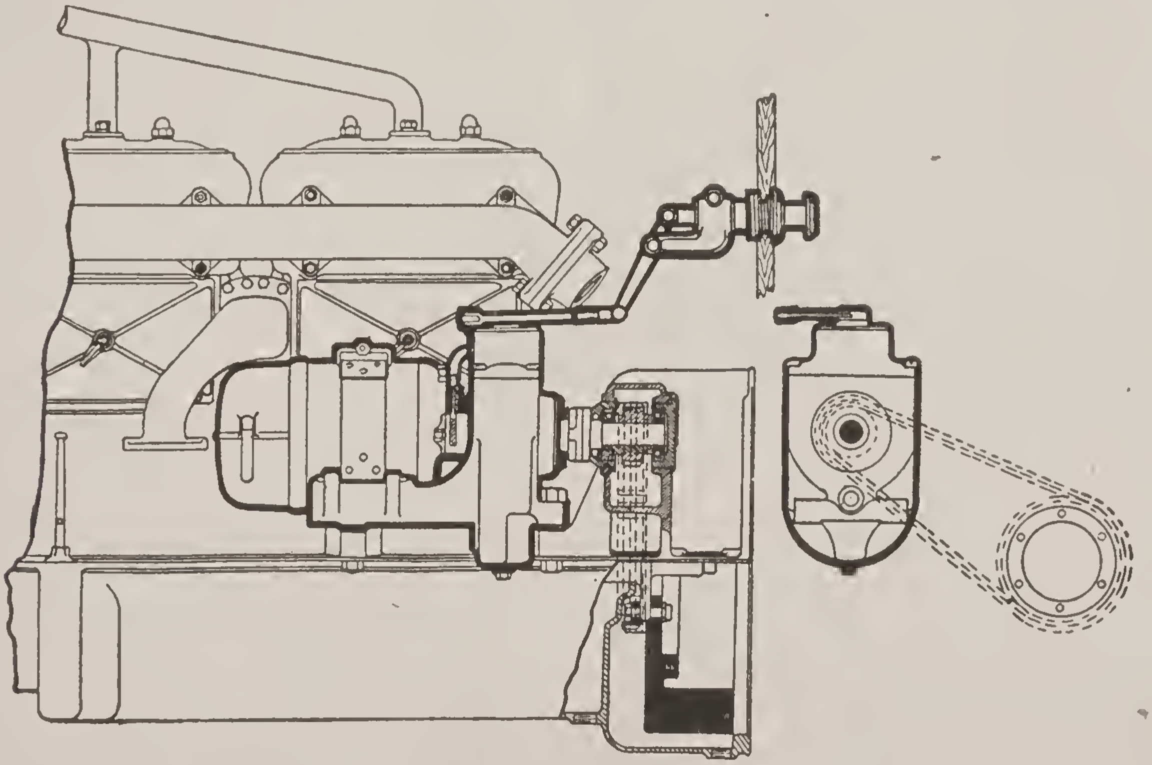


Fig. 162. Mounting and Drive of Northeast Dynamotor

motor designed for direct engagement with the flywheel gear. The purpose of the spring shown on the end of the shaft is to pull the pinion quickly out of engagement when the motor takes up its cycle, as explained in the following sections.

Driving Connections. Except in the case of the single-unit type, which is in a permanent driving relation with the engine, it is necessary to provide some form of driving connection with the engine in order that the electric motor may turn it over to start, and release it the moment the engine fires. The method of accomplishing this is made clear by a brief study of Fig. 164, which shows an Overland four-cylinder motor with an Auto-Lite two-unit system, the starting motor only being shown. In this installation the control button or starting pedal serves both to connect the motor with the battery and to engage the driving pinion with the toothed ring of the flywheel. Typical examples of this form of control are found on the Locomobile and Peerless, which differ only slightly in detail in their methods of installing the Gray and Davis starting motor. The switch is usually located directly beneath the footboards just back of the dash. Depressing the pedal part way makes preliminary contact through a resistance, turning the electric motor over very slowly, and at the same time draws the starter pinion toward the flywheel gear, its slow turning insuring easy engagement. As the pedal is depressed further, it breaks the first contact and closes the main switch, sending the entire battery current through the starting motor and turning the engine

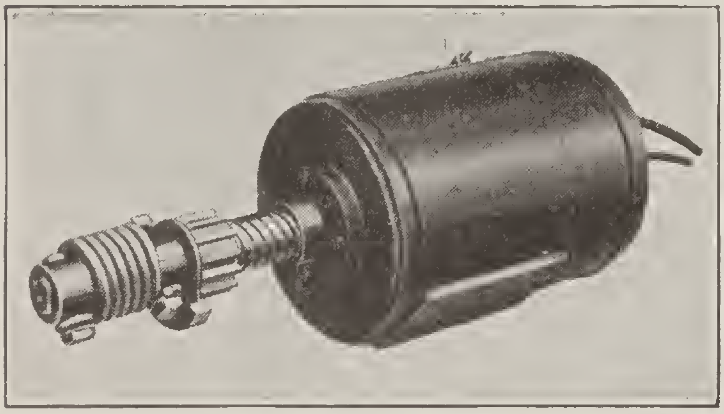


Fig. 163. Ward-Leonard Starting Motor for Direct Engagement

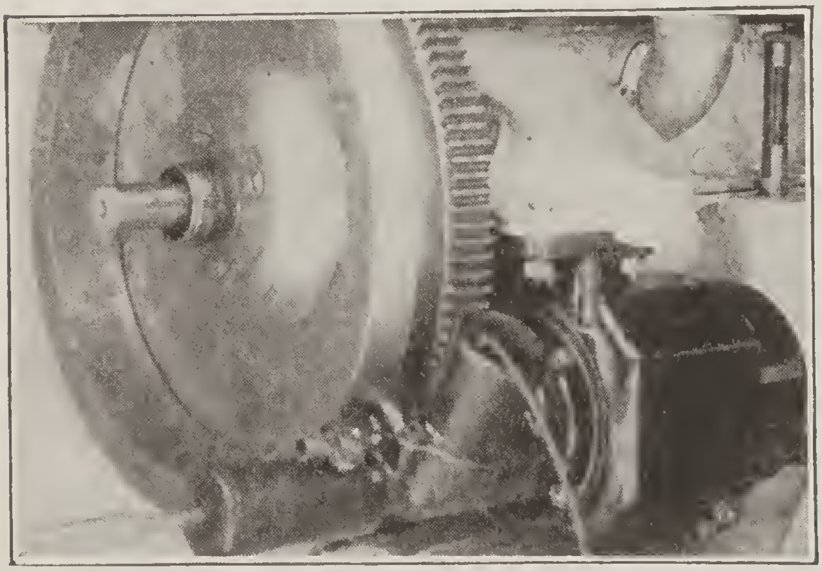


Fig. 164. Auto-Lite Starting Motor on Overland Engine

over rapidly. Releasing the pedal automatically opens the switch contacts and disengages the starting motor from the flywheel. It is also frequently made in the form of a pedal and placed on the slope of the footboards under the cowl of the dash, the location in any case being dictated by the necessity of keeping it out of the way of the other controls of the car.

Automatic Engagement. *Auto-Lite Type.* Fig. 165 illustrates an improvement on the foregoing method, which eliminates the necessity of mechanically engaging the starting pinion with the flywheel. This is an Auto-Lite generator on an Overland six motor. In starting, the depression of the pedal cuts in a resistance in the same manner, at first, as it would not only be unsafe to send the full strength of the current through the motor before it picked up the load, but it would also be impossible to mesh the pinion at full speed. In this starting motor, the pinion is cut on a sleeve surrounding the armature shaft of the motor, and this sleeve is normally held out of engagement by the spring shown. On the armature shaft a thread of coarse pitch is cut which engages the inner surface of the sleeve. When the starting motor begins to turn slowly as the current from the battery enters it through the resistance, centrifugal force moves the sleeve with the pinion along it toward the right until the latter meshes with the flywheel gear. As soon as the current is cut off, the spring draws the pinion out of engagement. This is known as the Bendix drive and is rapidly becoming standardized.

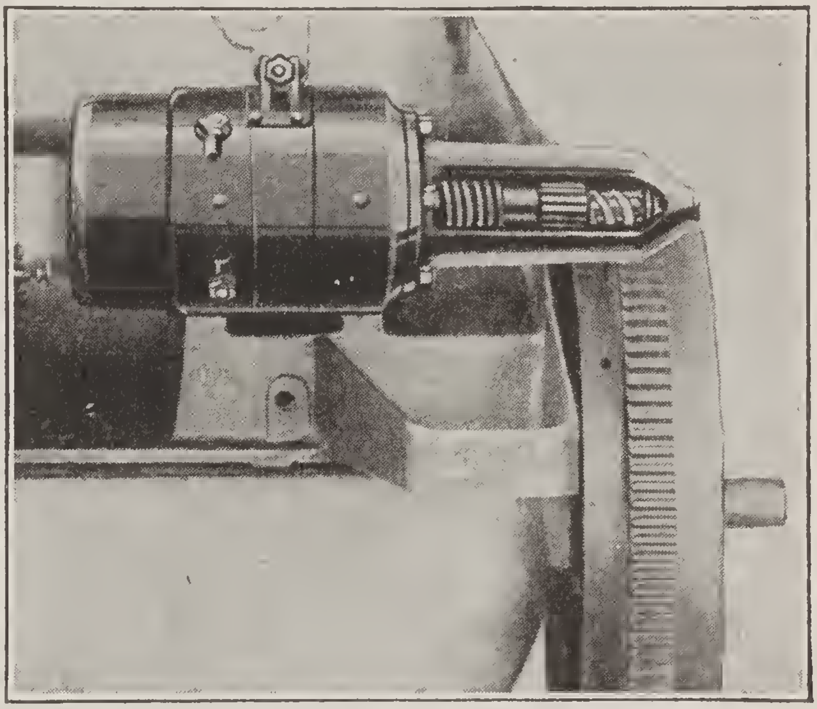


Fig. 165. Automatic Engagement and Release of Starting Motor, Overland Engine

Bosch-Rushmore Type. Another form of automatic engagement, which is electrically operated in this instance, is that of the Bosch-Rushmore starter. By referring back to Fig. 155, which shows a section of this starting motor, it will be noted that there is a heavy spring on the left-hand end of the armature shaft and that

the armature itself is normally held out of its usual running position by this spring. In other words, it is not centered in the armature tunnel but is two inches or more to the right of the center of the magnetic field. This is just sufficient to keep the pinion out of mesh when the motor is installed, as shown in Fig. 166. The first contact of the starting switch sends sufficient current for the field poles to exert enough magnetic drag on the armature to draw it back into its normal centered position, at the same time turning it over slowly, so that engagement is quickly effected automatically. The moment the current is shut off, the spring pushes the armature back and disengages the pinion. Exceptions to the practice reflected by the foregoing examples are to be found on cars like the Reo, in

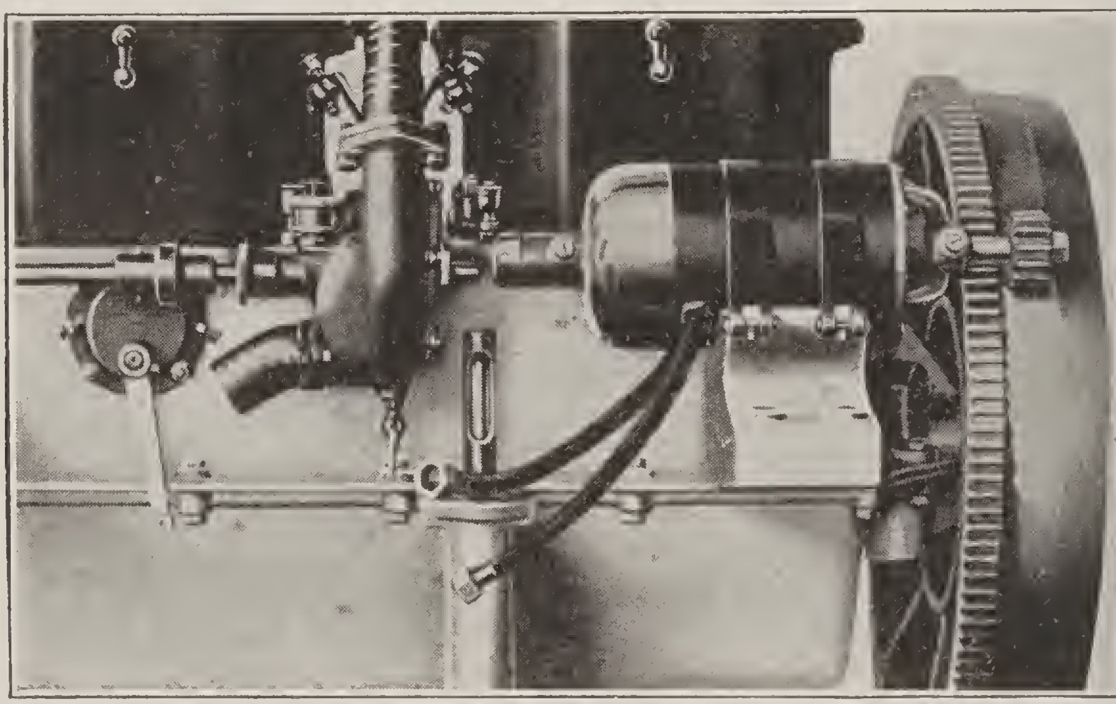


Fig. 166. Mounting of Bosch-Rushmore Starting Engine

which the Remy starting motor is mounted on the transmission housing and drives to one of its shafts through a worm and worm wheel. The latter lowers the speed sufficiently through a single reduction, and the revolution of the armature in starting picks up a clutch which automatically releases as soon as the engine starts.

Clutches. *Necessity for Disengaging Device.* To prevent the gasoline engine from driving the starting motor when the former takes up its cycle, some form of over-running clutch must be provided unless the starter is geared directly to the crankshaft or has a mechanical disengaging device, such as the Bendix or electrical, as the Bosch-Rushmore and Westinghouse. To take care of the speed reduction, assume that this gear ratio is 30 to 1 and that the throttle is half open

when the engine is being cranked. As soon as the explosions begin to take place, the engine will shortly speed up to about 500 r.p.m. Before the gasoline engine is started, however, the electric motor will be running pretty near its maximum rate, say 3000 r.p.m. An electric motor of this type will run as high as 5000 r.p.m. safely, but speeds in excess of this are liable to damage it. If the throttle of the engine should happen to be three-quarters of the way open when started and it should speed up to 1000 r.p.m. before the starting motor was disengaged, the armature shaft of the latter would attain a speed of 15,000 r.p.m., which is far beyond the safety limit. This makes it necessary to provide some device which, while permitting the starting motor to drive the engine, will prevent the latter from driving the starting motor as soon as the former takes up its regular cycle.

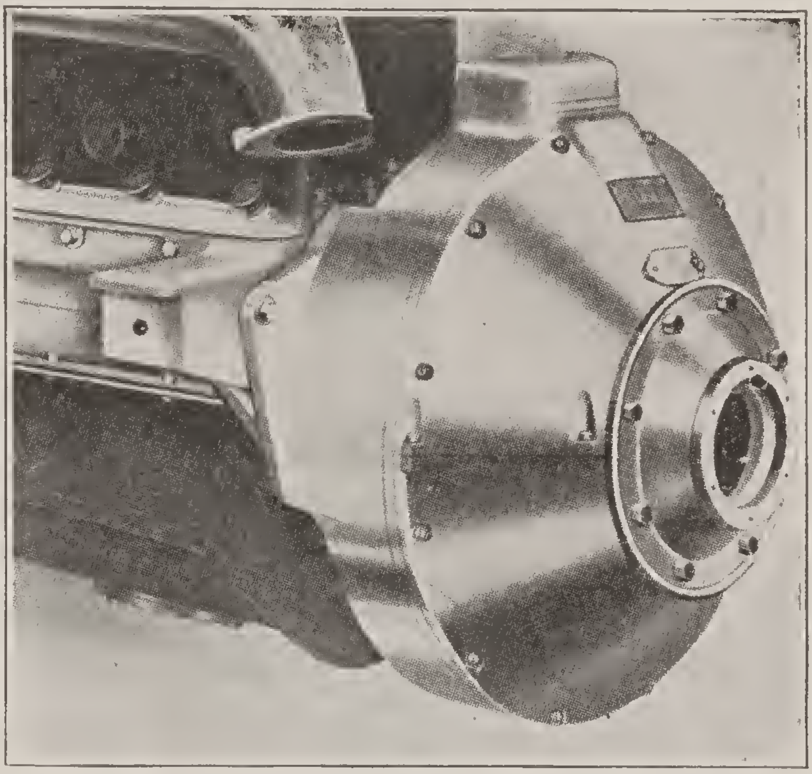


Fig. 167. U.S.L. Dynamo on Sheffield Simplex (British) Engine

A number of different devices are employed for this purpose, such as the jaw clutch similar to that employed on all handcranks, roller clutch, friction clutch, pawl and ratchet, inertia clutch, worm and worm wheel, and others. A description of one or two types will suffice to make clear the principle on which most of the mechanical devices are based. The roller clutch and the over-running jaw clutch are most frequently used. With starters of the design of the U.S.L., shown on a Sheffield-Simplex (British) six-cylinder motor in Fig. 167, it is obviously unnecessary to provide any form of flexible coupling, as the armature is mounted directly on the crankshaft and consequently cannot exceed the speed of the latter.

Where the crankshaft is driven direct through a train of gears or a combination of gears and a silent chain, the clutch is usually placed between the last gear of the train and the crankshaft. None of the gears is then in operation except when starting. On the

flywheel-gear type of installation used in connection with a second-gear reduction by means of a countershaft, Fig. 158, the clutch is placed on the countershaft. Otherwise, it is mounted on the armature shaft. In the case of a worm and worm-wheel drive, it is incorporated in the worm wheel.

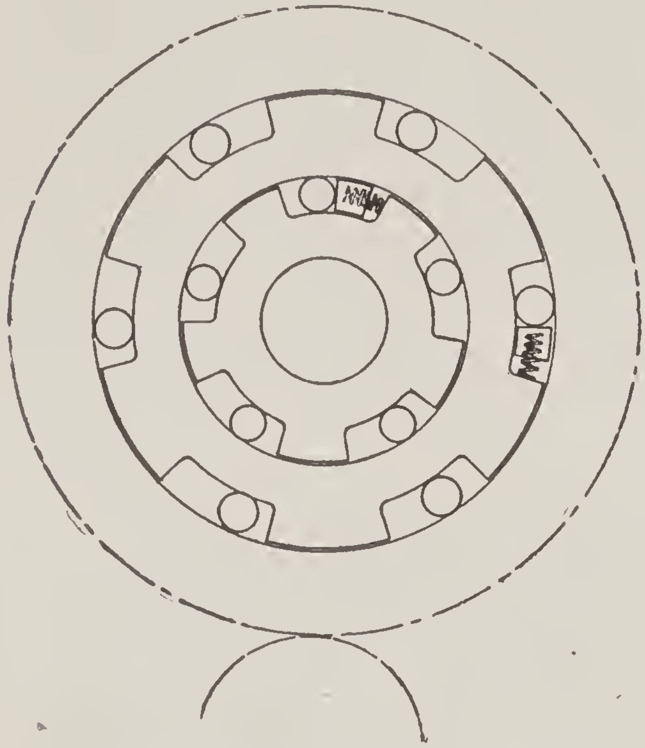


Fig. 168. North East Double Roller Over-Running Clutch (*Horseless Age*)

Roller Type. The roller type is the most commonly used and, as the various forms in which it is made differ but little, a description of one will suffice to make clear the principle employed. It consists of an inner driving member and an outer driven member, connected by a number of rollers when the driving member is rotated in one direction and disconnected when it is rotated in the opposite direction, i.e., when the driven member tends to run faster than the driver. Fig. 168 shows the double-roller over-running clutch employed on the North East dynamotor. A double clutch is employed in this case to permit the dynamotor to be driven at one speed when operating as a dynamo and at another when starting the engine. Fig. 169, which shows the Leece-Neville starter on a Haynes six-cylinder motor, is an example of the use of a roller clutch and chain in place of the gear and pinion connection previously described.

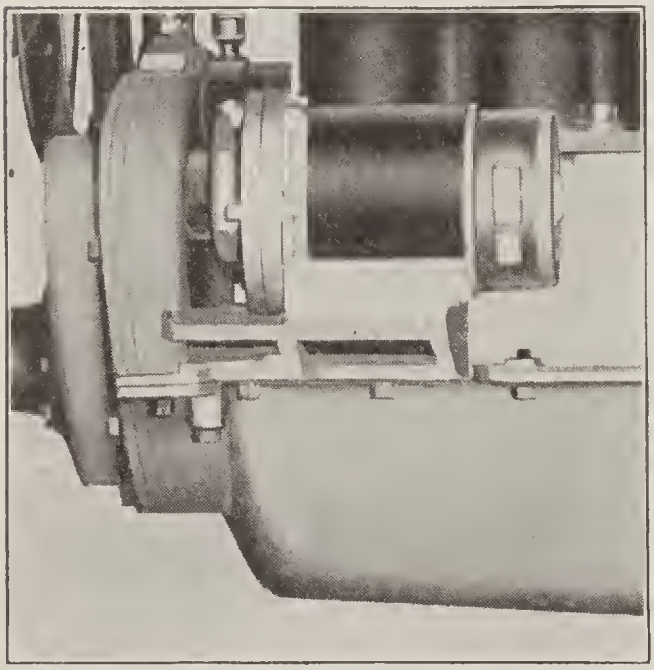


Fig. 169. Leece-Neville Starter Installation, Haynes Motor

Back-Kick Releases. As the starting motor has more than sufficient power to overcome a back-kick or premature explosion (with the spark-timing lever too far advanced) of the engine, and is only slowed down by it, only a few instances of the employment of

a back-kick release are found in practice. One of these on the Northeast starter is in the form of a friction clutch held in contact by springs. This clutch will slip under such circumstances. A friction disc clamped between two steel discs, similar to a shock absorber, is employed on the Hartford starter, this being required because of the irreversible worm and worm-wheel drive used, as the teeth of the latter would be injured in case the engine "back-kicked". Another device employs a brake band on the starting gears so designed that it holds in one direction only.

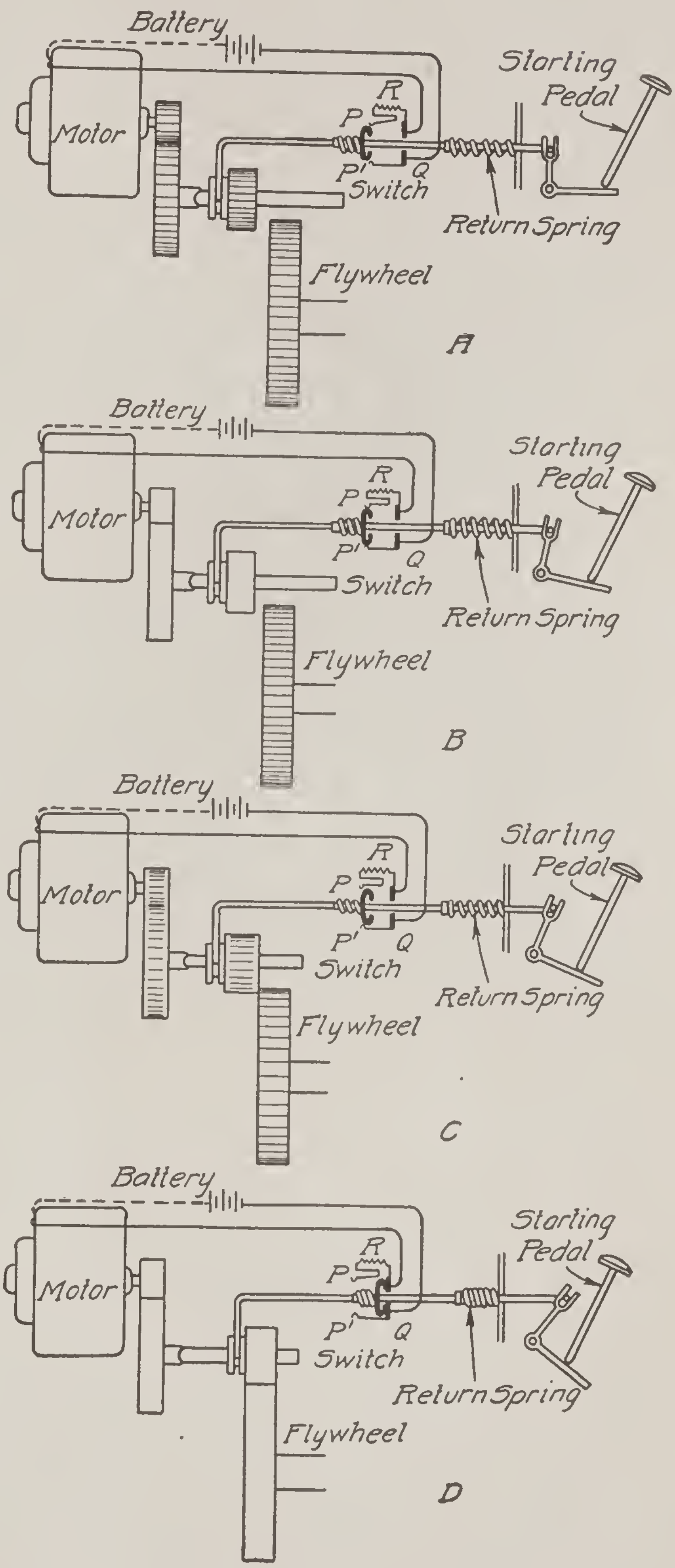


Fig. 170. Diagrams of Electrical and Mechanical Connections of Motor and Switch for Flywheel Drive with Double-Gear Reduction (*Westinghouse*)

Switches. Two types of switches are employed in connection with starting and lighting systems—those designed to control the lighting circuits to the various lamps, and those employed to connect the battery with the starting motor. As the first type seldom carries more than 5 amperes at 6 volts and proportionately less at higher voltage, it does not differ from the standard forms of switches employed for house lighting, except that it is made much smaller in size. The starting switch, on the other hand, has to carry currents ranging from 50 to 250 amperes or more at voltages varying from 6 to 24, so that such a switch must be well built mechanically and have liberal contact

areas. On account of the heavy currents handled by these switches there is a tendency to destructive arcing at the contact points unless provision is made to prevent it.

Westinghouse Starting Switch. For starting use, two forms of switches are employed according to the method by which the motor starts the engine. Where the motor is connected directly to the battery terminals by the switch, as in the case of single-unit systems such as the Delco, only a single set of contacts is necessary; but in case gears must be engaged before the starting motor can take the full battery current, two progressively operated sets of contacts are used. The first set completes the circuit through a heavy resistance to turn the starting motor over very slowly, and the second set cuts out this resistance, the driving gears then being engaged. The operation of a switch of this type is graphically illustrated by a series of sketches,

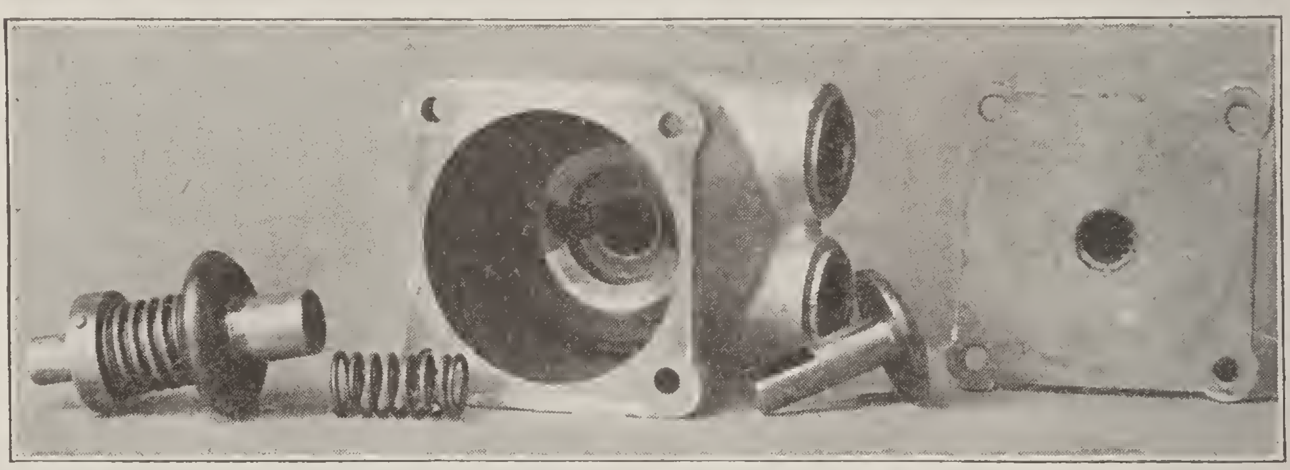


Fig. 171. Details of Westinghouse Switch

Fig. 170, showing a Westinghouse starter installation. In sketch *A*, both contacts are open, the return spring holding them apart. When the starting pedal is partly depressed, as in sketch *B*, the first set of contacts *P* come together and current from the battery passes to the starting motor through the resistance *R*. This connection continues through the spring fingers *P* and *Pl* until the sliding member is almost in contact with the main-switch points *Q*, when it is broken and the circuit is directly closed with the battery by a butt contact. The operation only requires a fraction of the time necessary to describe it. The moment the foot is removed from the starting pedal, the return spring automatically breaks the circuit. The construction of this switch is shown in Fig. 171. Switches of this type are usually mounted directly under the footboards, a slight movement being sufficient to close the contacts. The starting plug may be removed by

the driver when leaving the car to prevent tampering, a pin across the tube making it impossible to insert a pencil or stick. The resistance mentioned is in the form of a ribbon and is incorporated in the switch.

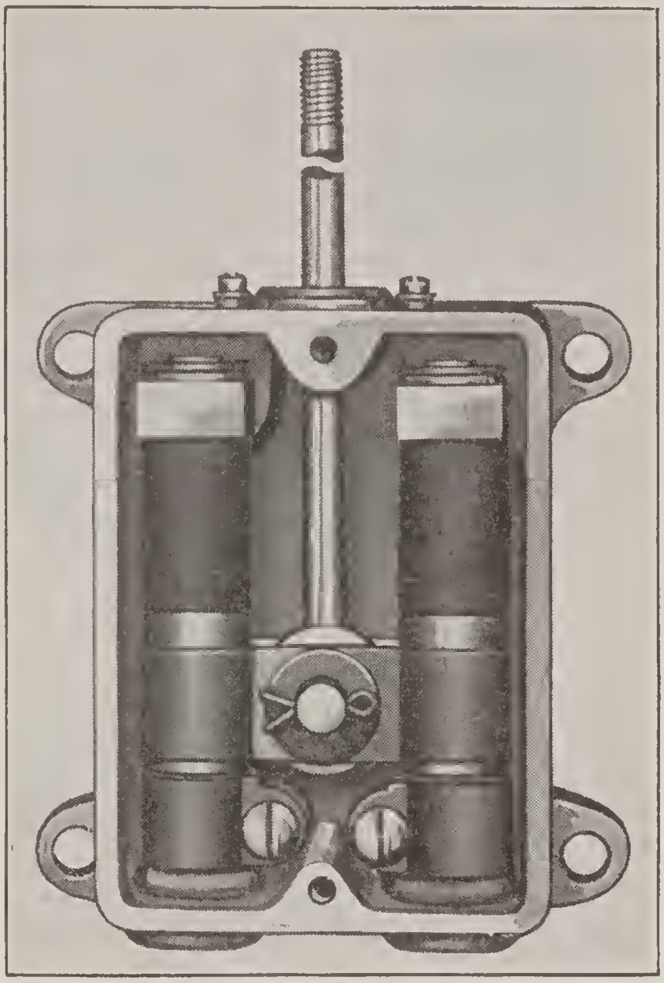


Fig. 172. Remy Starting Switch

Miscellaneous Starting Switches. The type of switch used in connection with the Remy system is shown in Fig. 172. Both this and the Westinghouse switch described are known as butt-contact switches. The knife type of switch is also employed in several systems, Fig. 173 showing the Dean switch of this class. A somewhat unique form of contact is shown in the Gray and Davis switch, Fig. 174. There being no starting gears to mesh, it is only necessary to turn the current directly from the battery into the motor to start. *P* is the foot button of the starter, *F* the floorboard of the car, and *T* and *M* the terminals of the switch from which cables are led to one side of the battery and to one of the motor brushes, the others being grounded, as this is a single-wire system. Into the cast

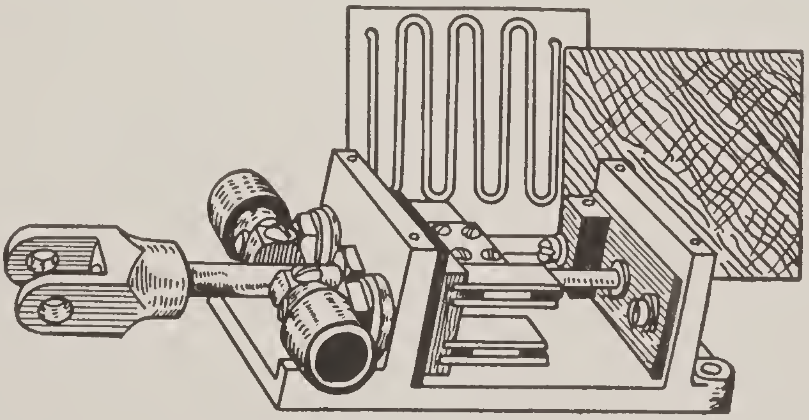


Fig. 173. Dean Knife Starting Switch

receptacle of the switch is fitted an insulating disc carrying the contacts *C* and *O* and also serving to insulate the terminals. These contacts are circular in form, and their free ends are turned away from each other so as to slip down over the knives *R* and *S* set in the insu-

lated disc. The contacts are pressed downward by P, which is returned by the spring G pressing against the spindle P. The terminals T and M are fastened to the semicircular knives R and S, respectively, so that bringing down the contacts C and O upon these knives

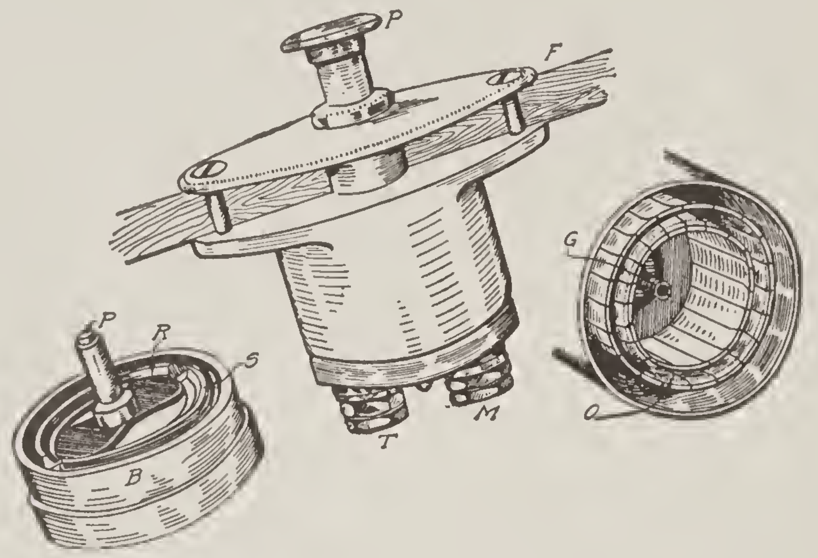


Fig. 174. Gray and Davis Button Starting Switch

completes the circuit from T to M. Numerous other forms of foot-operated switches are also employed, the Gray and Davis laminated contact switch, Fig. 175, for flywheel-gear installations, and the Ward-Leonard "harpoon" type, Fig. 176, being representative examples.

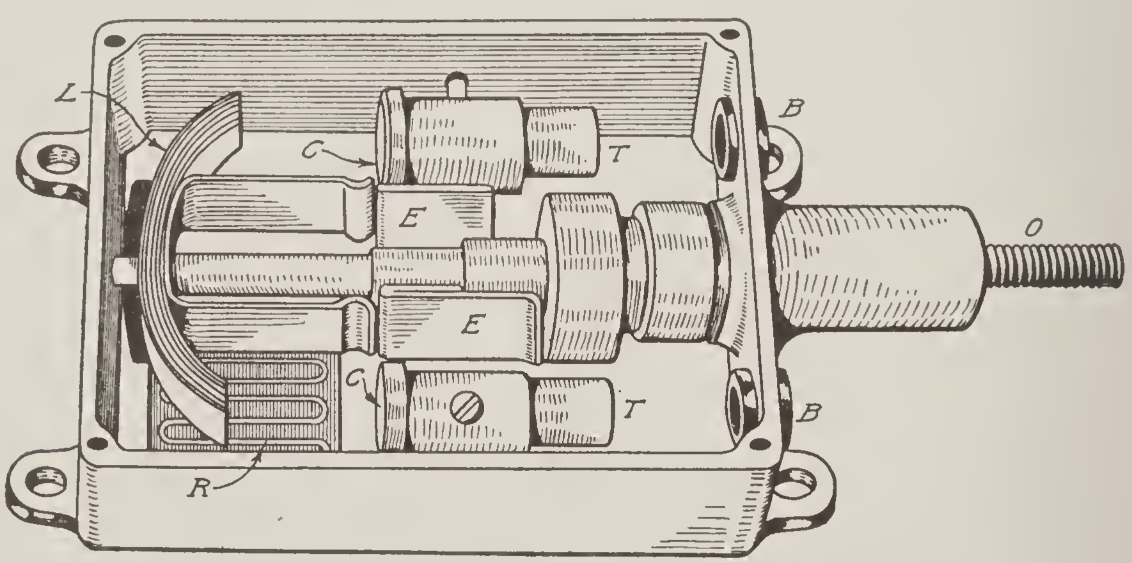


Fig. 175. Gray and Davis Laminated Type of Starting Switch
Courtesy of The Horseless Age

Electrically Operated Switches. In this type a conventional push-button switch, either on the dash or mounted on the steering column, as shown in Figs. 177 and 178, which illustrate the Packard and Overland control, respectively, takes the place of the foot button. This push-button switch, however, only handles a shunt current of low value, which energizes a solenoid to close the contacts of the main

switch and also to engage the gears where this is necessary. The Westinghouse magnetically operated switch is explained in detail in connection with the description of that system. This form of control is employed on electric-railway trains and on electric automobiles. In addition to housing the push-button switch of the starting system, the two steering column control units mentioned also incorporate all the switches necessary to control the entire electrical equipment of the car, as will be noted by the indications alongside the various buttons on the Overland controller. A complete wiring diagram of the Packard six-cylinder controller is shown in Fig. 144.

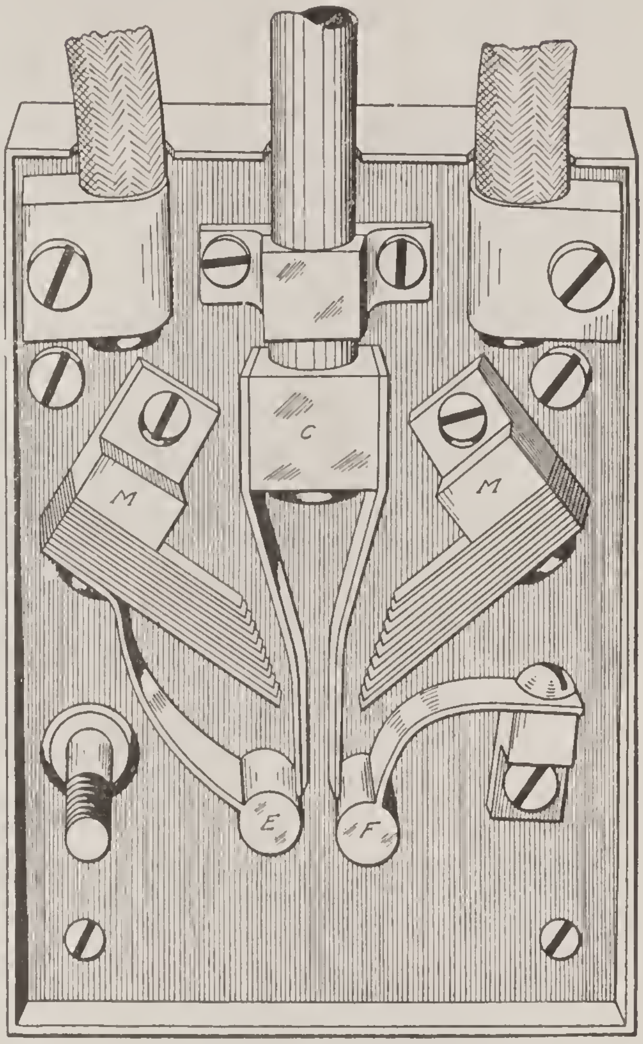


Fig. 176. Ward-Leonard "Harpoon" Starting Switch

Where a higher potential than the usual 6-volt standard is employed, the switch has another function, which is that of changing the battery connections from the multiple arrangement used for lighting to the series connection necessary to send the full voltage and current of the battery through the starting motor. This is the case with the U.S.L. system, which is made in either 12—6-volt or 24—12-volt forms.

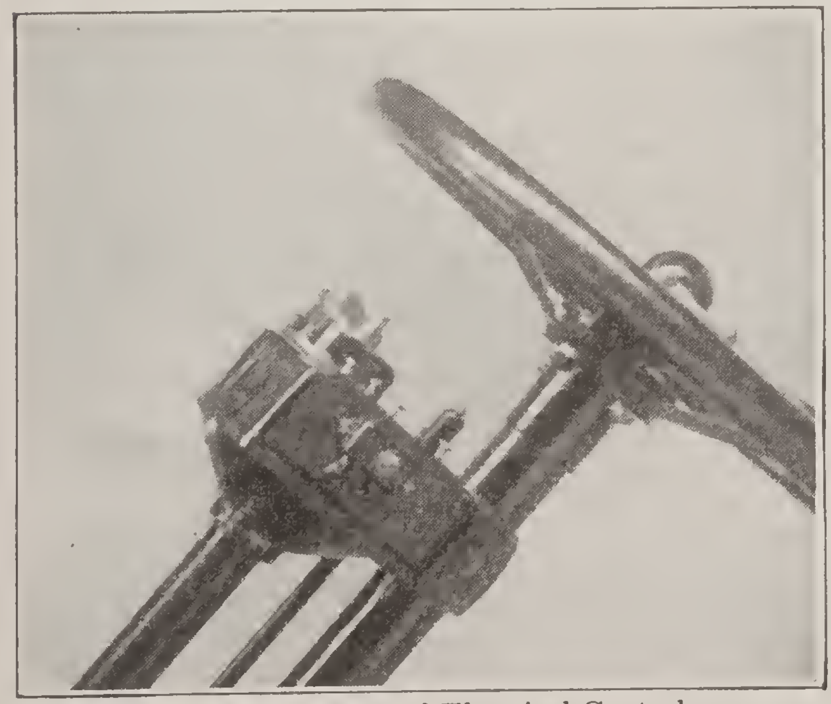


Fig. 177. Packard Electrical Control

Fuses. Standard practice favors the employment of fuses on all the lighting circuits to protect the battery in case of short-circuits

in any of the wiring. They were originally considered unnecessary on two-wire systems, but have since been adopted on the latter as well as on the single-wire system. Such fuses are of the cartridge type of miniature size, as shown in Fig. 179, which represents a Westinghouse fuse block, and do not produce a flash when they blow, which is a safety feature of importance in the presence of gasoline. The appearance of a black spot on the label indicates that the fuse has burned out, or these fuses may be had in glass tubes through which the fuse wire is visible.

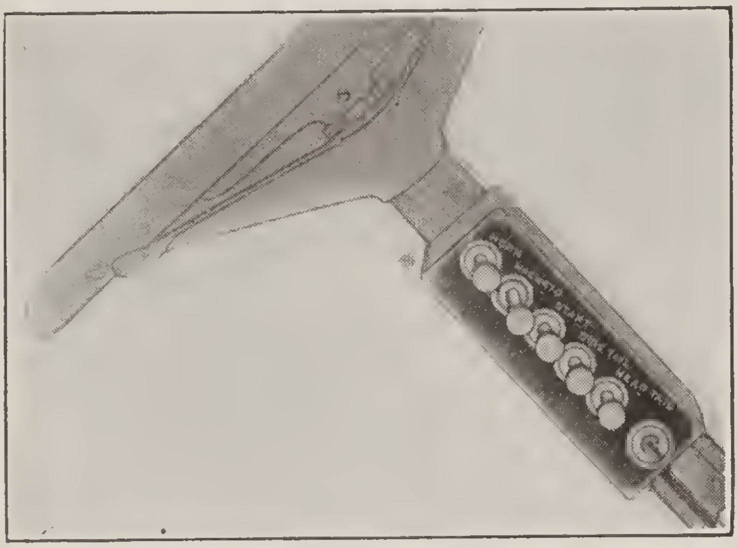


Fig. 178. Overland Electrical Control

A double reading ammeter, mounted on the dash and illuminated at night by a hooded lamp, shows whether current is being sent into the battery or being taken out of it, the needle usually moving over a scale to the right of the neutral line for charging and to the left for discharging, Fig. 180. This dash lamp is usually connected in series with the tail lamp, so that when it goes out it is an indication that the tail lamp is out as well. A voltmeter sometimes is provided to indicate the condition of the battery. In the Bosch system, this is combined with the lighting switches, as shown in Fig. 181.

Fig. 179. Type of Fuse Employed on Lighting Circuits

In some systems, an indicator is employed instead of an ammeter, a movable target appearing at a small opening in the instrument and simply reading "Off" and "On" or "Charge" and "Discharge". Such an instrument need not be so accurate as an ammeter and is more durable. These indicators never came into general use, however, and will be found on comparatively few cars, usually models of two or three years ago.

Electric Horns. The use of a storage battery which is of sufficient capacity for starting purposes and which is kept constantly charged by the lighting generator has made it possible to employ numerous auxiliary electrical devices. The electrical horn is the chief of these, and it has to a very large extent displaced warning devices of every other class. Two different types of electric horns are used, in both of which the sound is produced by the vibrations of a sheet-metal diaphragm several inches in diameter. The only difference between the two forms lies in the method of causing this diaphragm to vibrate, one employing a small electric motor and the other a simple electric magnet. Fig. 182, which is a phantom view of the operating mechanism of a Klaxon horn, shows the first type. On the upper end of the armature shaft of the electric motor is fastened a toothed wheel which strikes the button in the center of the diaphragm and sets it vibrating at the rate of several thousand times per minute, giving rise to the raucous squawk which has come to be identified with automobile warning signals. As shown in Fig. 183, which illustrates a section of the Apollo horn, this type is nothing more nor less than an ordinary buzzer on an enlarged scale.

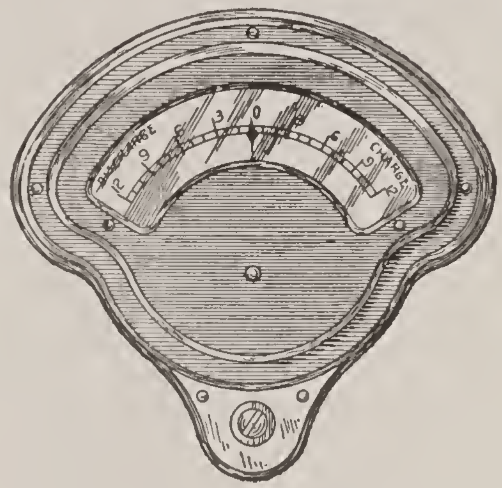


Fig. 180. Gray and Davis Ammeter

Fig. 181. Bosch Voltmeter and Switches

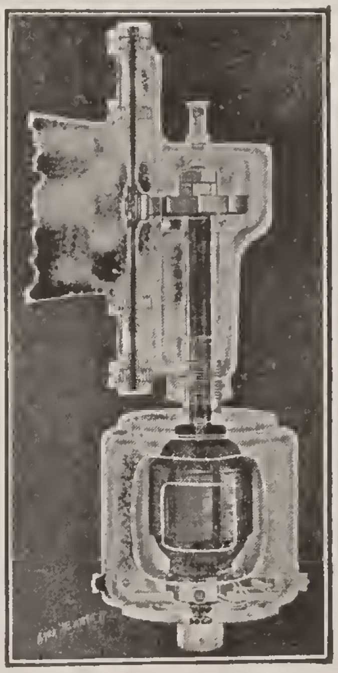


Fig. 182. Phantom View Klaxon Horn

The armature of the electromagnet vibrates at high speed producing a sound by taps on the rod attached to the diaphragm.

Care of the Electric Horn. As the operation of the electric horn is based upon exactly the same principles as the essentials of the starting and lighting systems, the instructions given for the care and adjustment of the latter will apply to it as well. In the case of the motor-driven type of horn, the commutator and brushes of the motor will require attention from time to time. Failure to operate may be due to a broken connection at the horn or at the battery; ground in the circuit between it and the battery; brushes not bearing properly on the commutator; or an excess of oil and dirt on the latter. If the motor runs properly, but the horn produces either no sound or a very weak sound, the trouble will be due to the poor contact of the toothed wheel with the button on the diaphragm. This button is made

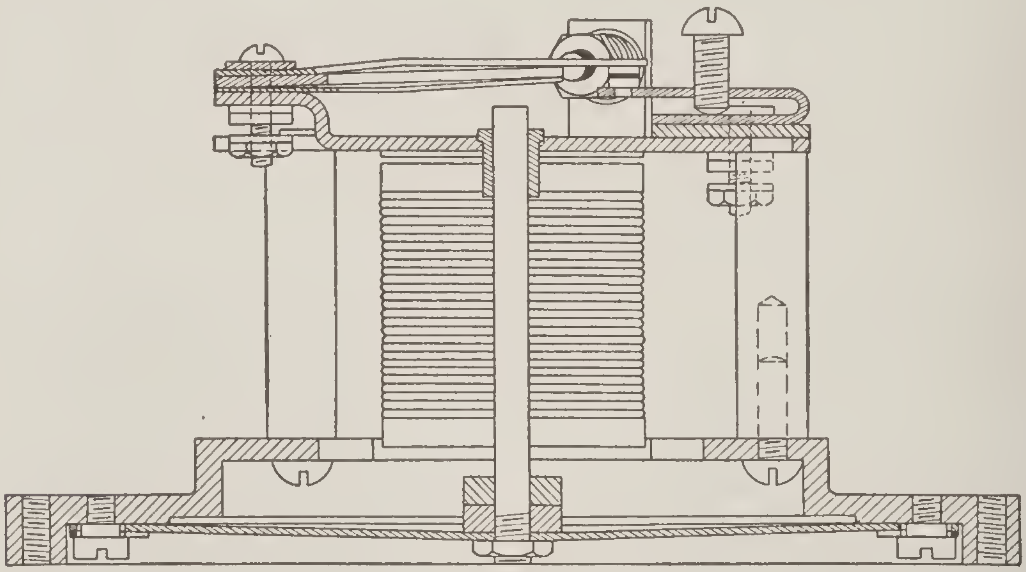


Fig. 183. Mechanism of Apollo Electric Horn (*Horseless Age*)

glass hard to obviate wear at that point, but, in time, replacement of either the button or the toothed wheel or of both may be necessary.

The attention required by the vibrating type of horn, of which there are many thousands in use, is very similar to that described for the battery cut-out and the voltage regulator. The contact points will require cleaning, truing up, and adjustment at intervals, and the spring may also need occasional attention. Failure to operate may be caused by a loose connection or break in the circuit, or by a lack of adjustment which causes the contacts to be held apart so that no current can pass through the winding of the electromagnet. A weak sound from this horn will result either from insufficient current or from lack of adjustment.

LIGHTING

For automobile headlights, side lamps, tail lamps, and general illumination, electric lighting has superseded all other systems. In the best electric-lighting systems the current is supplied by a dynamo driven constantly by the engine, with a storage battery auxiliary.

Incandescent Lamps. *Tungsten and Other Filaments.* Incandescent lamps are usually provided with tungsten filaments. These filaments are much shorter and much stronger than in standard lamps, a condition that is further contributed to by the necessities of low voltage and high amperage, which require short and thick rather than long and thin filaments. A good tungsten lamp will afford 1 candle power of illumination for each 1.2 watts of current.

Mazda Type. Fig. 184 shows the standard types of lamps generally used. These are Westinghouse Mazda lamps for 6 volts, those at the left being 15 c.p. headlight lamps; the next two, 6 c.p.

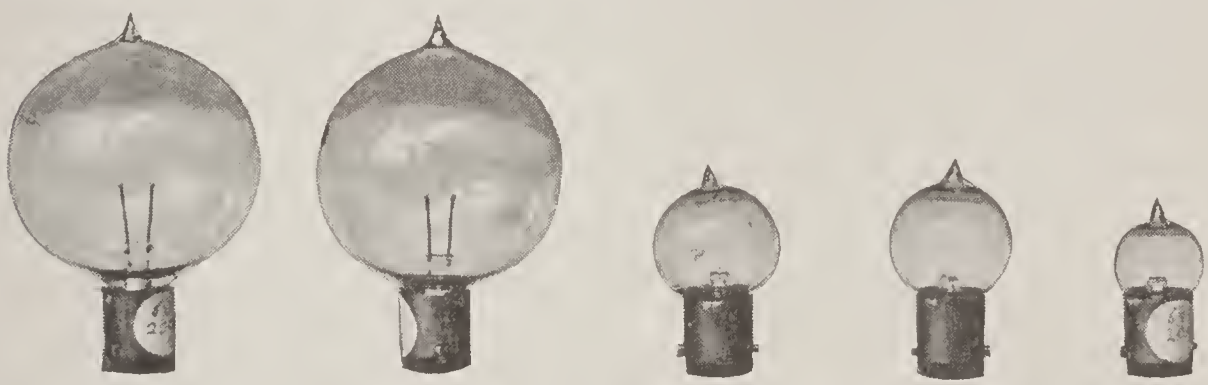


Fig. 184. Westinghouse Lamps—Head, Side, and Tail

side-light lamps; and the smallest one is a 2 c.p. size designed for the tail light, meter light, and for interior lighting of closed cars. At 6 volts, the 15 c.p. lamps require 2.5 amperes, the 6 c.p. side lights 1.25 amperes, or where 4 c.p. lamps are employed—a better size for the purpose—.85 ampere; the 2 c.p. lamps take .42 ampere. The larger lamps have the filament in the form of a spiral coil occupying the minimum space so that the whole source of light can be placed at the exact focus point of the paraboloidal reflector.

Bosch Type. Fig. 185 shows the Bosch lamps, which are of special form. The headlight lamp at the right is of 25 c.p. and has the filament stretched horizontally across wire supports, while the side lamps of 8 c.p. have a loop of corrugated wire, and the tail lamp, of tubular form, a single filament running straight across it. Tail lamps are usually in series with the instrument lamp so that failure of the latter to light also indicates a failure of the tail lamp.

Lamp Voltages. When Edison was asked how he came to hit upon 110 volts as the standard for incandescent lighting, he said he "just guessed it". Evidently the 6-volt standard

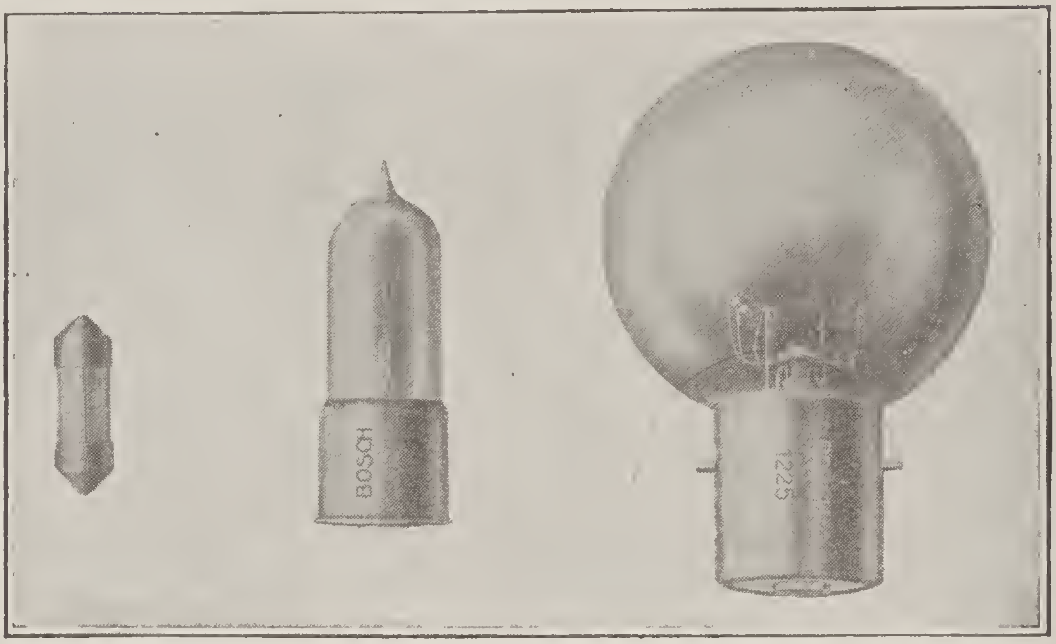


Fig. 185. Bosch Type Automobile Incandescent Bulbs

came about in pretty much the same way. It is not practicable to operate small lamps at a high voltage, as the lamp of that type requires a long slender filament. Many manufacturers of starting apparatus have deemed it necessary to employ a higher voltage, but the lamps are usually run at 6 volts, so that the batteries employed are accordingly some multiple of 3, as 6, 9, or 12 cells, giving 6, 12, 18, or 24 volts. Where more than three cells are used, this necessitates operating the lamps from a part of the battery, which is not advantageous, as it involves discharging the battery unevenly. As a battery capable of delivering current at 12 volts weighs and costs about 35 per cent more than one giving current at 6 volts and the attention required is greater, the lower voltage is generally favored.

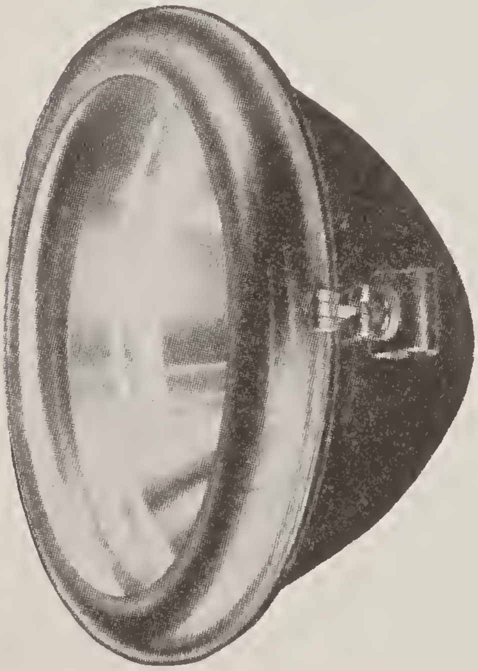


Fig. 186. Typical Electric Automobile Headlight

Lighting Batteries. The only type of batteries suitable for electric lighting—except for very small tail lamps, which can be successfully kept in operation by dry cells—are storage batteries of the lead types, as described in Part VIII.

Reflectors. Much attention has been directed to the problem of defining the best type of reflectors for automobile headlights, and the conditions of lighting by acetylene gas have been determined to be very different from those involved when electric lighting is used.

Parabolic Type. A typical electric headlight for automobile use is that illustrated in Fig. 186. The plain form affords a minimum tendency to catch dirt and mud and greatly simplifies cleaning. The position of the lamp is adjusted to give correct focus, as this is essential to give a properly projected beam of light ahead on the road.

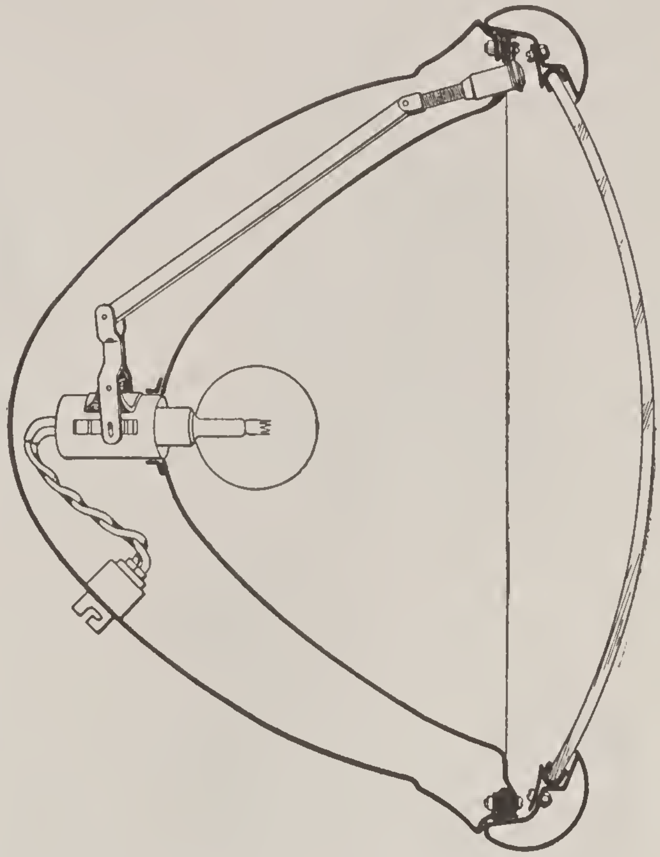


Fig. 187. Section of Fig. 183

Comparison of Parabolic with Lens Type. The reflector in the foregoing lamp is of the deeply parabolic metal type, illustrated in Fig. 187. The advantage of this type of reflector is that it intercepts a much larger proportion of the light rays from the lamp than the lens-mirror type of reflector, Fig. 188.

Types for Various Locations. Fig. 189 *-a*, *-b*, *-c*, *-d*, and *-e* show the usual types of lamps employed. These are, in the order given, an outside side lamp, flush-type side lamp, two types of electric tail lamps, and a cowl or dash lamp for illuminating the instruments, such as the ammeter, oil telltale, and the like. Fig. 189-*f* shows a magnetic trouble-hunting lamp, the base of which attaches itself to any metal part of the chassis.

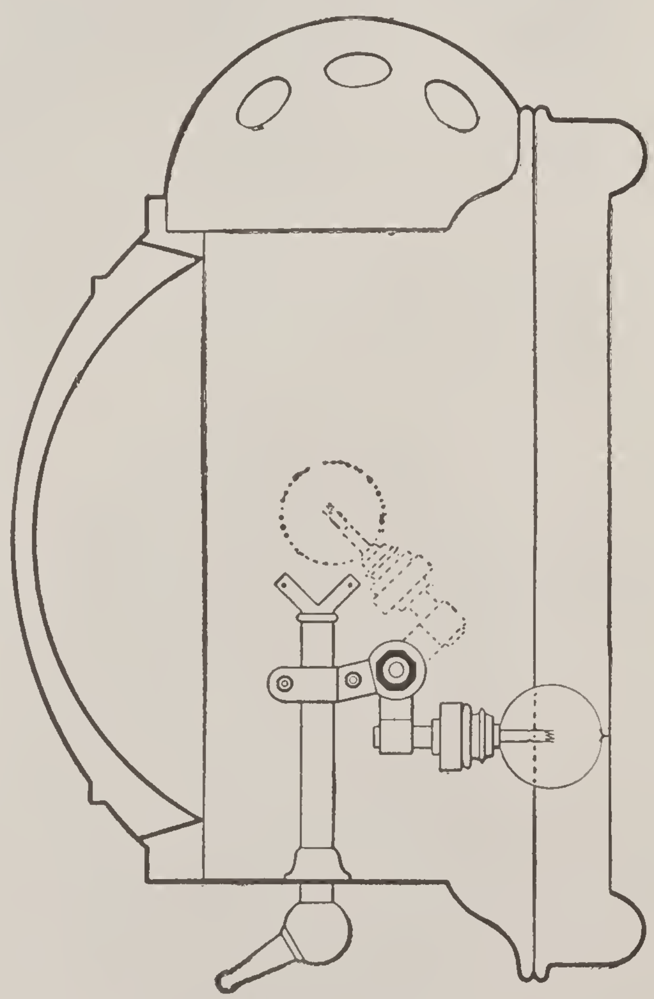


Fig. 188. Mangin Lens Reflector

Headlight Glare. The increased efficiency of electric headlights has brought with it, in far more aggravated degree, the blinding

Fig. 189. Types of Side, Dash, Tail, and Trouble-Hunting Lamps

glare first experienced with the acetylene lamps. Originally, strong headlights bothered pedestrians; but since the introduction of electric lighting, they have been objected to most strongly by automobilists themselves, because to the driver of an automobile, the blinding glare from the headlights of an approaching car means not only annoyance but danger. Acuteness of vision is wholly destroyed for a period of thirty seconds or more during which only a slow-down to a walking pace will insure absolute safety to the automobilist, as a pedestrian or the usual black and lampless buggy are practically invisible.

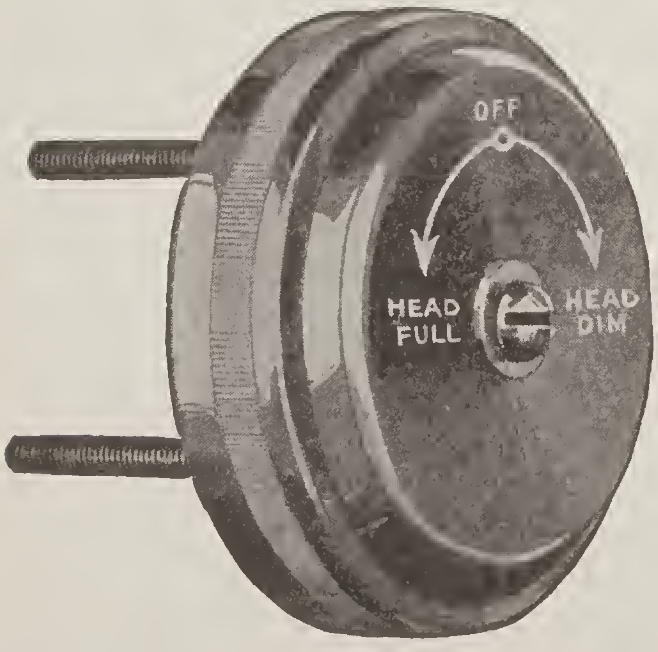


Fig. 190. Type of Headlight Dimming Switch

Dimming Devices. Owing to the fact that glare and illumination are so closely related and that there is no objection to glare on deserted country roads where the necessity for road illumination is greatest, permanently dimmed lights are naturally not practicable.

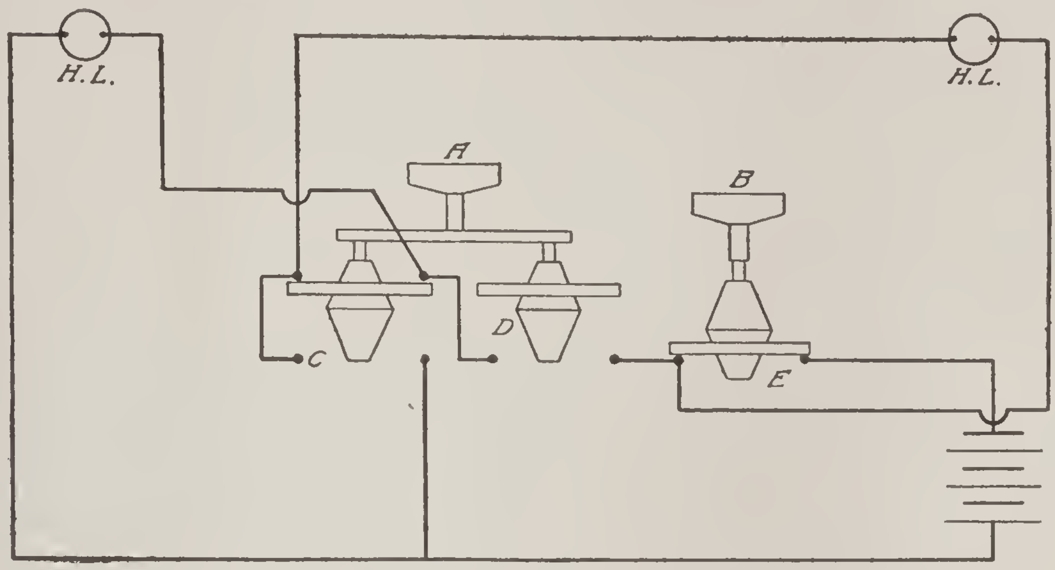


Fig. 191. Wiring Diagram of Parallel Control for Dimming Headlights
Courtesy of Horseless Age, New York City

What is required is a device under the control of the driver, so that either the full illuminating power of the head lamps or a subdued or dispersed light, free from glare, may be had as required.

A great many fundamentally different devices have been offered as a solution of the problem. While differing radically, practically

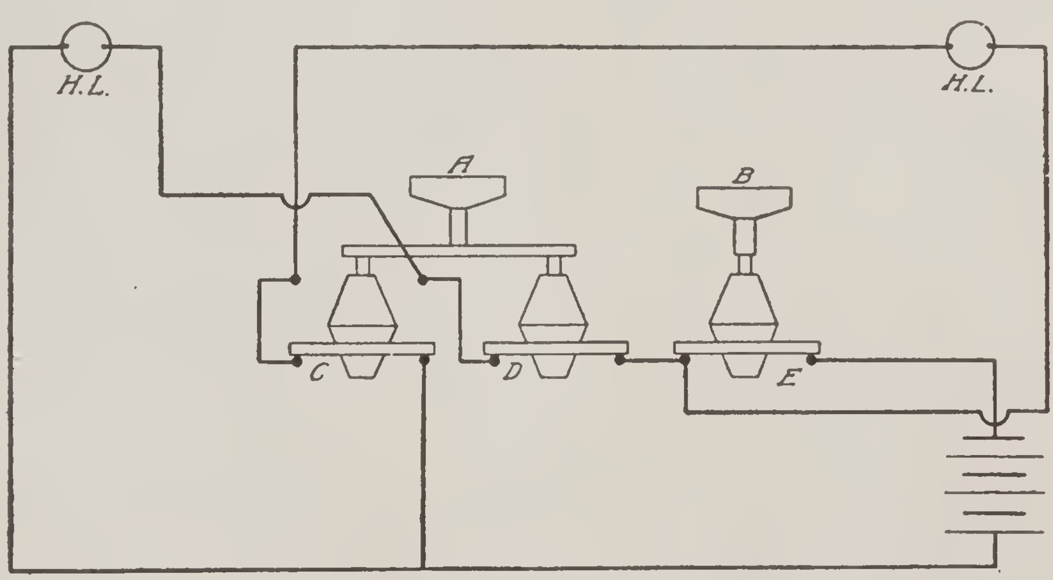


Fig. 192. Wiring Diagram of Series Control for Dimming Headlights
Courtesy of Horseless Age, New York City

all of them may be classed under two heads, i.e., electrical and mechanical.

Electrical Devices. One of the simplest of this class that has met with considerable favor is nothing more nor less than a *resistance* that may be inserted in the circuit of the headlights by turning a

small switch, mounted either on the steering wheel or in some other easily accessible location. This cuts the voltage down and causes the lamps to burn a dull red, instead of the filaments being the dazzling white reached at full incandescence. A dimmer of this type is shown in Fig. 190. An equally simple and practical device is a switch to throw the headlights into series for a dim light and back into parallel again when full illumination is desired. With the series connection, the current must pass through both lamps successively and each bulb thus receives but half the voltage and, as even a comparatively

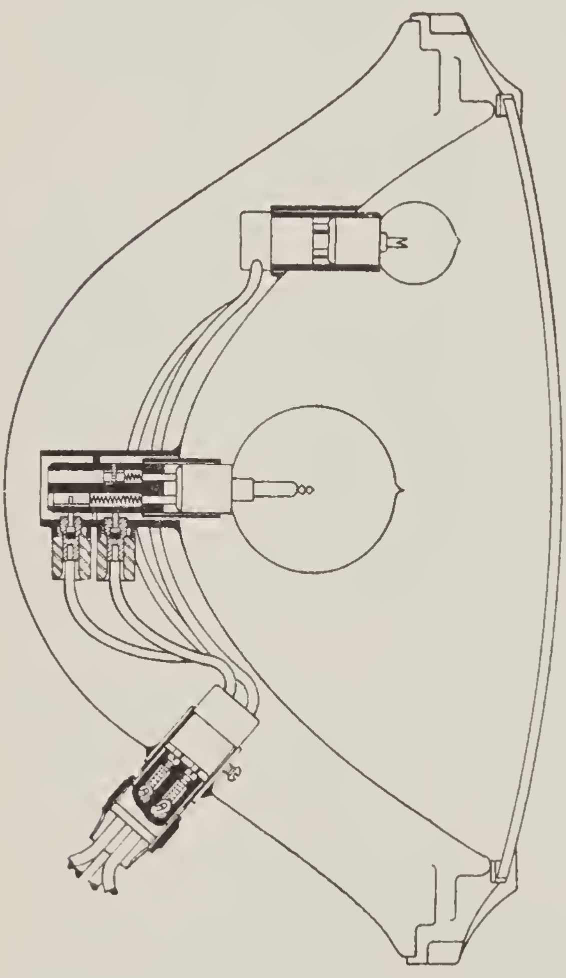


Fig. 193. Section of Hall Double Headlight

Fig. 194. Jeffery Double Filament Lamp

slight drop in voltage causes the efficiency of an incandescent lamp to fall off very markedly, the same result is attained. It is equivalent to burning a 6-volt lamp on a 3-volt current. With the normal, or parallel, connection, the current flows through each lamp separately, and both receive the full voltage of the battery so that they burn at full brilliance. A switch of this kind is marketed by the Cutler-Hammer Company. Fig. 191 illustrates the connections for parallel arrangement, or full illumination, switches *D* and *B* being closed and the button *A* pulled out to make *C* contact with its lower set of

connections. Fig. 192 shows the connections for series burning, effected by pulling out button *B* and pushing in *A*, this closing switch *E*, opening *D*, and contacting *C* with the upper connections.

The use of *two bulbs in each headlight* is also commonly resorted to, the method of effecting this being shown in Fig. 193. The second bulb is of the size ordinarily employed for side lights and is, moreover, entirely out of the focus of the reflector, so that the diminished light produced is entirely without glare and is mostly diverted downward.

A similar end is attained by the use of *two filaments in the same bulb*, as shown in Fig. 194. The lower filament in this case is employed for full illumination, and the upper, which is out of focus, for the dimmed light. This has the disadvantage that the burning out of either one of the filaments makes it necessary to replace the lamp, while both filaments also require the same amount of current.

PRACTICAL ANALYSIS OF TYPES

EXPLANATION OF WIRING DIAGRAMS

Significance of Symbols. To be successful in running down the cause of defection in a starting and lighting system on a car involves, first of all, a knowledge of the most likely places to seek the trouble. Unless the trouble is very apparent or becomes so upon making the simplest tests, a process of elimination must be carried out, and, to do this with any degree of system, the trouble hunter must be perfectly familiar with wiring systems in general. To the uninitiated, wiring diagrams are nothing more than a jumble of lines, queer figures, and confusing signs. Familiarity with these signs, in consequence, is the first thing to achieve. Their direct bearing upon the varying relation of the essentials described in the introductory on Electrical Principles, Part I, will at once be apparent.

Current Direction. The plus and minus, or positive and negative signs, + positive, − negative, scarcely call for any extended explanation. They indicate the direction in which the current flows. It is of the utmost importance, where the manufacturers' directions are to connect certain apparatus with a given wire to the plus, or positive, side, and another wire to the negative, that these instructions be followed explicitly. Otherwise, the apparatus either will refuse to work or it may be damaged, as in the case of a storage battery on which the connections have been reversed. Wherever

+ Positive

— Negative

Fig. 195. Battery, Either Storage or Dry Cells

Fig. 196. Generator, Commutator, and Brushes

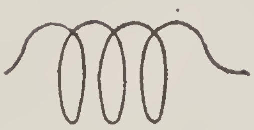


Fig. 197. The Proper Method of Showing a Coil Which Surrounds an Iron Core but Very Seldom Used on Delco Drawings

Fig. 198. The Method Used in Showing a Coil Where There Is No Chance of Confusion—Used in Field Coils, Ignition Coils, Etc.

Fig. 199. The Method Used to Show Resistance Such as a Resistance Unit and Charging Resistances

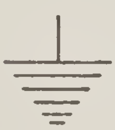


Fig. 200. Ground Connection Where the Wire Is Connected to the Chassis, Engine, or Generator

Fig. 201. Contact Points Such as in Switches, Distributors, Etc.

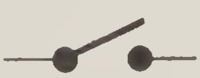


Fig. 202. Method Used to Show Lighting Switches

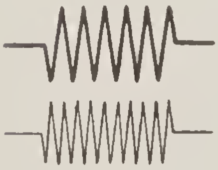


Fig. 203. Primary and Secondary Windings of an Ignition Coil

Fig. 204. Condenser

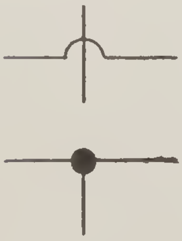


Fig. 205. Upper Showing Crossed Wires not Connected. Lower Showing Connection in the Wiring

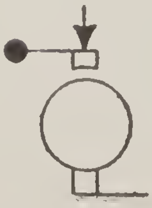


Fig. 206. Motor Commutator and Brushes with Brush Lifting Switch

it is necessary that the current flow through a piece of apparatus in a certain direction, the manufacturer stamps plus and minus signs at the terminals.

Battery; Generator. A battery, regardless of its type, is always shown by alternate heavy and light lines, as indicated in Fig. 195, each pair of lines representing a cell, so that the number of cells in the battery may be told at a glance. Other sources of current, such as generators, are indicated by a conventional sign consisting of a circle with two short heavy lines tangent to its circumference at opposite points and usually at an angle to the horizontal, as shown in Fig. 196. The origin of this sign will be apparent in its resemblance to the end view of a commutator with a pair of brushes bearing on it. This sign is also used to indicate a motor, in which case the letter **M** is inserted in the circle.

Coils. Coils which are wound on an iron core are generally indicated by a conventional sign consisting of a few loops of wire, as in Fig. 197, but this is only the case where such a coil occurs at a place in the circuit where there might be a chance of confusion in identifying it. Where there is no possibility of confusion—as in the case of the windings of a generator or motor, ignition coils, and the like—the sign shown in Fig. 198 is often used. Where the lines are heavy, a coarse wire, such as is employed for series windings of generators or motors, or the primary winding of an ignition coil, is intended.

Resistance. Resistance in a circuit is usually shown by an arbitrary sign, Fig. 199, similar in outline to a piece of the cast-iron grid frequently used in charging resistances, though sometimes shown as a coil and marked "resistance".

Grounds. The sign of a ground connection is the inverted pyramid of short lines, Fig. 200, and indicates that the circuit is grounded. This may be either by a wire directly connected at some point with the frame, as in the case of the storage battery, or it may be through an internal ground connection in the apparatus itself, as in the lamps and sometimes the generator or motor, the connection being made simply by fastening them in place. In any case, the sign indicates that the circuit is completed through a ground.

Contacts. There are a number of signs employed to indicate contact points, switches, and the like, and, where they are not of an

arbitrary character, such as Fig. 201, which shows contact such as used in switches, distributors, etc., and Fig. 202, which indicates a lighting switch (Delco diagrams); they usually will be found to bear sufficient resemblance to the apparatus itself to make their identification easy.

Induction Coil. Fine lines indicate a generator shunt winding, the secondary of an ignition coil, or the coil of a relay or cut-out. The primary and secondary windings of an induction coil as used for ignition are indicated by a fine and a coarse coil sign, as in Fig. 203.

Condenser. A condenser with its overlapping plates is shown in Fig. 204.

Crossed Wires. To show wires that cross one another without making connection, a half loop is made at that point to show that the wires do not touch, as in Fig. 205, while wires that are connected are shown by a black dot at the junction.

General and Special Usage. While these signs are not universally used in exactly the form shown here, their employment is very general and in the majority of cases, such as the positive and negative, battery, ground, generator, induction-coil windings, and coil signs, they are never changed. In some instances special signs are employed, such as that shown in Fig. 206, which indicates the motor commutator of the Delco single-unit machine or *dynamotor*, and shows the special brush lifting switch. Incandescent lamps are almost always indicated by small circles, though the lamp itself is sometimes drawn in. As a matter of fact, very little system is followed by different makers in making these wiring diagrams. In an effort to simplify its reading to the uninitiated, a diagram will sometimes picture most of the apparatus in such form that it will be recognized from its resemblance to the original, including the battery, generator, lamps, and the like, using only signs for showing coils and ground connections; others go to the opposite extreme and show nothing but signs.

Diagrams for Single-Wire System

Buick-Delco Type. For purposes of illustration a very simple diagram is selected, Fig. 207. This is the Delco single-unit system as employed on an earlier model of the Buick. Starting at the left

side of the diagram, the generator is shown with its shunt-field winding, one brush of the generator and the shunt coil being grounded. This is a complete circuit, but, as the shunt coil has a high resistance, only a very small part of the current flows through it. The series winding of the generator is shown at the top and the explanation that this is a "reverse" series coil means that it is wound to have a polarity opposite to that of the shunt coil. It accordingly opposes the shunt coil at the higher speeds and serves to regulate the output of the generator. This is the familiar bucking coil or "reversed compound winding".

To reach the battery, the current from the generator must pass through the automatic cut-out, the two windings and the contact points of which are shown a little

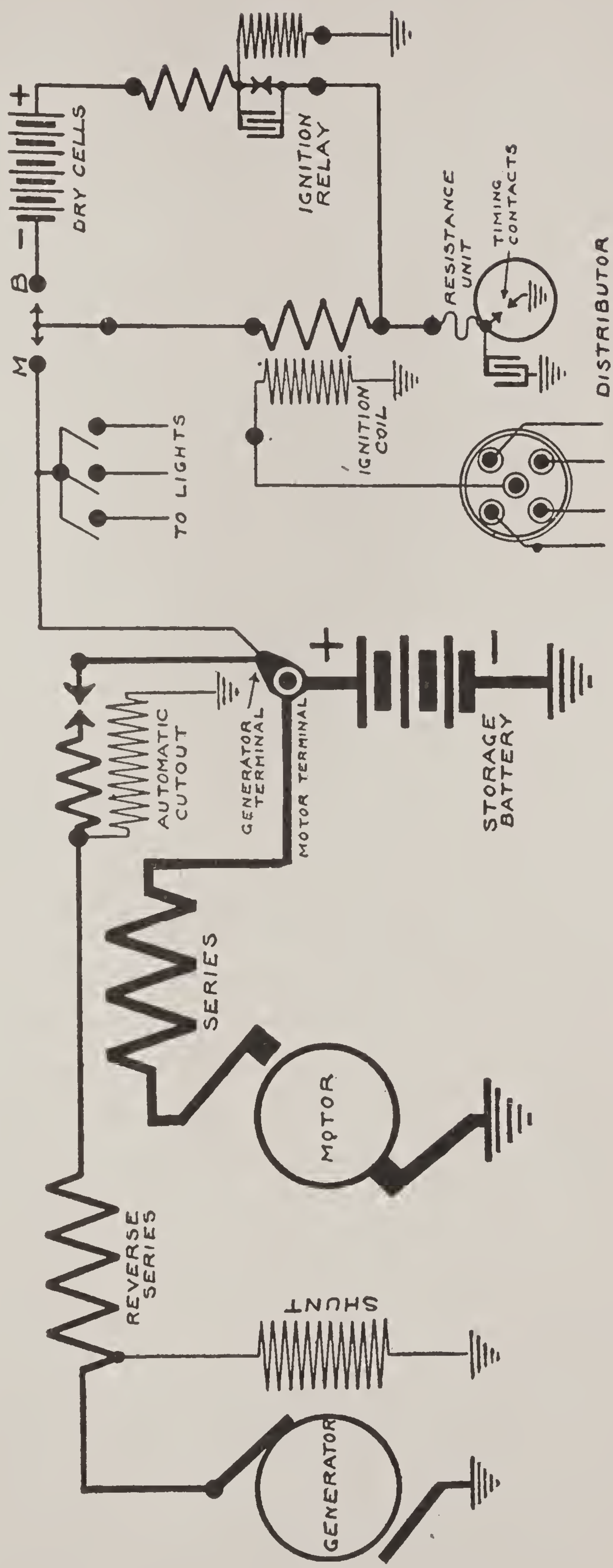


Fig. 207. Wiring Diagram for Delco Single-Unit Single-Wire System

further to the right along the top line. If the ammeter on the dash fails to register any charging current when the engine is running at a speed equivalent to 10 miles an hour or more, the automatic cut-out would be the first place to seek a break in the system. Under normal conditions of working, the cut-out closes the circuit as soon as the generator reaches a certain speed and the 3-cell storage battery, one side of which is grounded, is then being charged, the current entering at the plus or positive terminal and returning by way of the minus terminal or pole through the ground connection. (In some systems, such as the Gray & Davis, the frame of the car is the positive side of the circuit.)

Between the generator and battery circuits is shown the starting-motor circuit. The width of the lines employed indicates that very heavy conductors are used in this circuit and they are necessary owing to the extremely heavy currents handled. The series winding of the motor field is also short and of heavy wire. The upper brush of the motor being in a raised position indicates that the motor is brought into operation through a switching brush, and when this switch is closed to start, one of the generator brushes is raised from the commutator. This completes the generating, starting, and controlling circuits, all of which are shown to the left of the battery. The relative difference in thickness between the wires of these circuits at the left and those at the right for the lighting and ignition show the difference in the amount of current handled by the two. The double set of contact points at the center along the top line indicate the dash switch—turning this to the left giving the magneto connection M, while throwing it to the right B puts in the battery of six cells shown just a bit further to the right in the ignition circuit. To the left of this dash switch a tap has been made for the lights, the three circuits of which, head, side, and tail are indicated but not completed, the draftsman often taking it for granted that complete detail connections are unnecessary. Another instance of this will be seen just below the lighting switch, the leads from the high tension distributor (four indicating a 4-cylinder motor) ending up a short distance from it, as it is obvious that they lead direct to the spark plugs.

The primary and secondary windings of the induction coil (ignition)—the former of which is grounded through a resistance

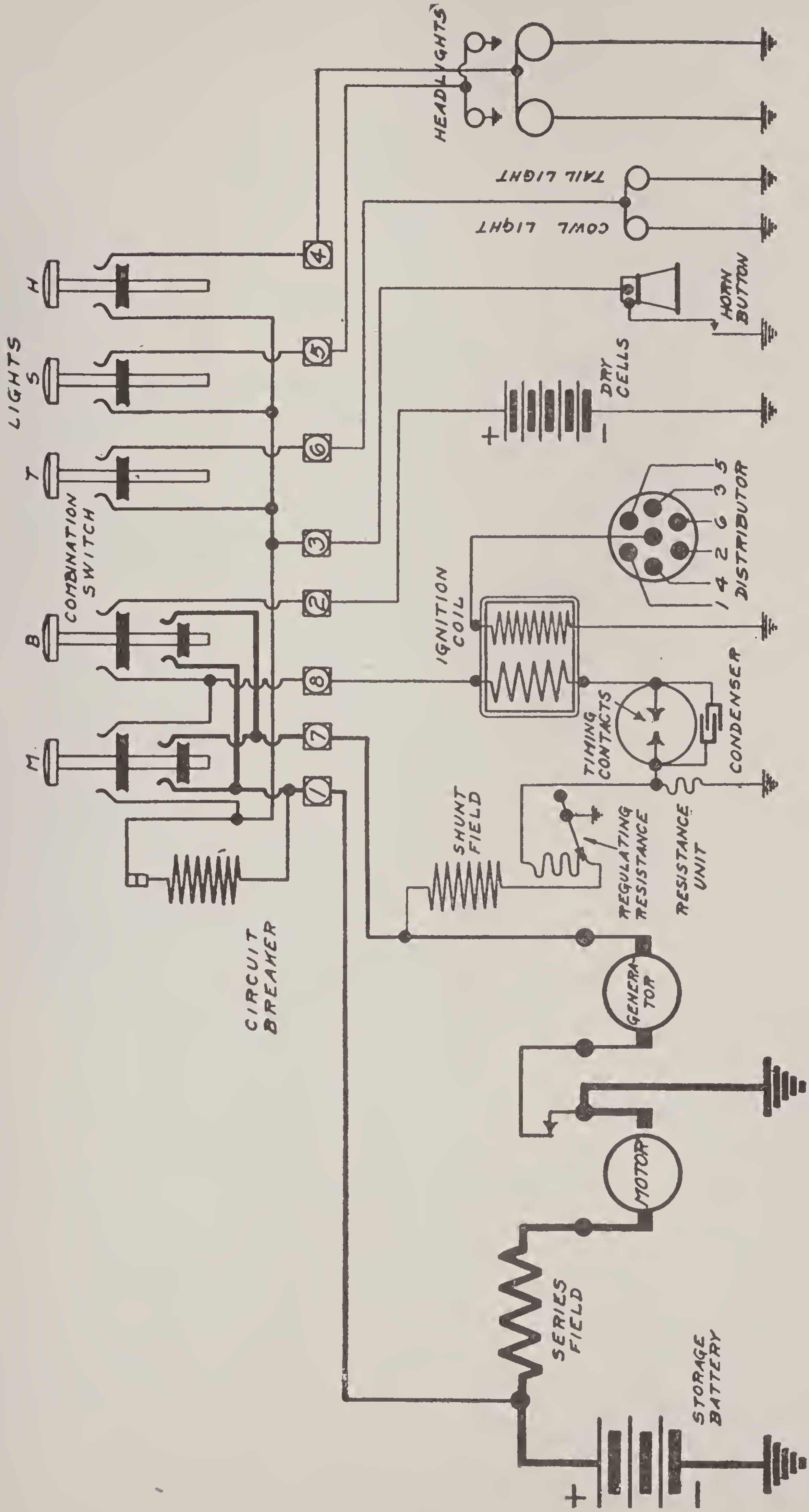


Fig. 208. Wiring Diagram for Delco Single-Unit System on the Auburn Six-40

unit and the timer, and the latter directly—are plain. But it also will be noted that a condenser is shunted around the sparking contacts of the timer, one side being connected to the contact terminating the positive side of the circuit, while the other is grounded. The function of a condenser here is to absorb the charge or surge of current due to the sudden opening of the contacts (breaking of the circuit) and to prevent the formation of an arc which would burn the contact points away rapidly. Badly pitted or burned contact points accordingly are an indication that the condenser has broken down or become disconnected from the circuit. This also will be evident from the excessive sparking at these contacts when the engine is running. The secondary winding of the coil is grounded directly. At the right-hand end of the diagram is seen the independent circuit of the dry-cell battery for emergency use in starting. The current from this battery passes through a relay coil the contact points of which are also provided with a condenser for the purpose already explained.

Auburn-Delco Type. The wiring diagram of the Delco lighting, starting, and ignition system of the Auburn, Model 6-40, Fig. 208, is more completely shown than the one to which reference was made above, in that all the switching connections are indicated and the lamp circuits have been carried out. Examination will also show that it differs in other respects as well. For example, instead of a bucking-coil type of regulator winding, the generator output is controlled through a variable resistance in the shunt-field circuit, the amount of resistance increasing with the speed. As the current through the shunt coil decreases with the increase in resistance, the fields are weakened and the generator output falls off.

Instead of the usual magneto-and-battery switch a special form of combination switch is shown in this wiring diagram which controls two circuits simultaneously, the generator-battery circuit and the circuit breaker-ignition coil circuit. These are discussed further in the main Delco section.

Diagram for Two-Wire System

Chevrolet-Auto-Lite Type. The wiring diagrams already explained are what are known as "single-wire" or grounded systems, there being but a single wire connecting any piece of apparatus to the source of current supply, the return side of the circuit being through the frame of the car. While usually referred to as the

"return" side of the circuit, the steel sections forming the frame of the car may be utilized for either the positive or negative side.

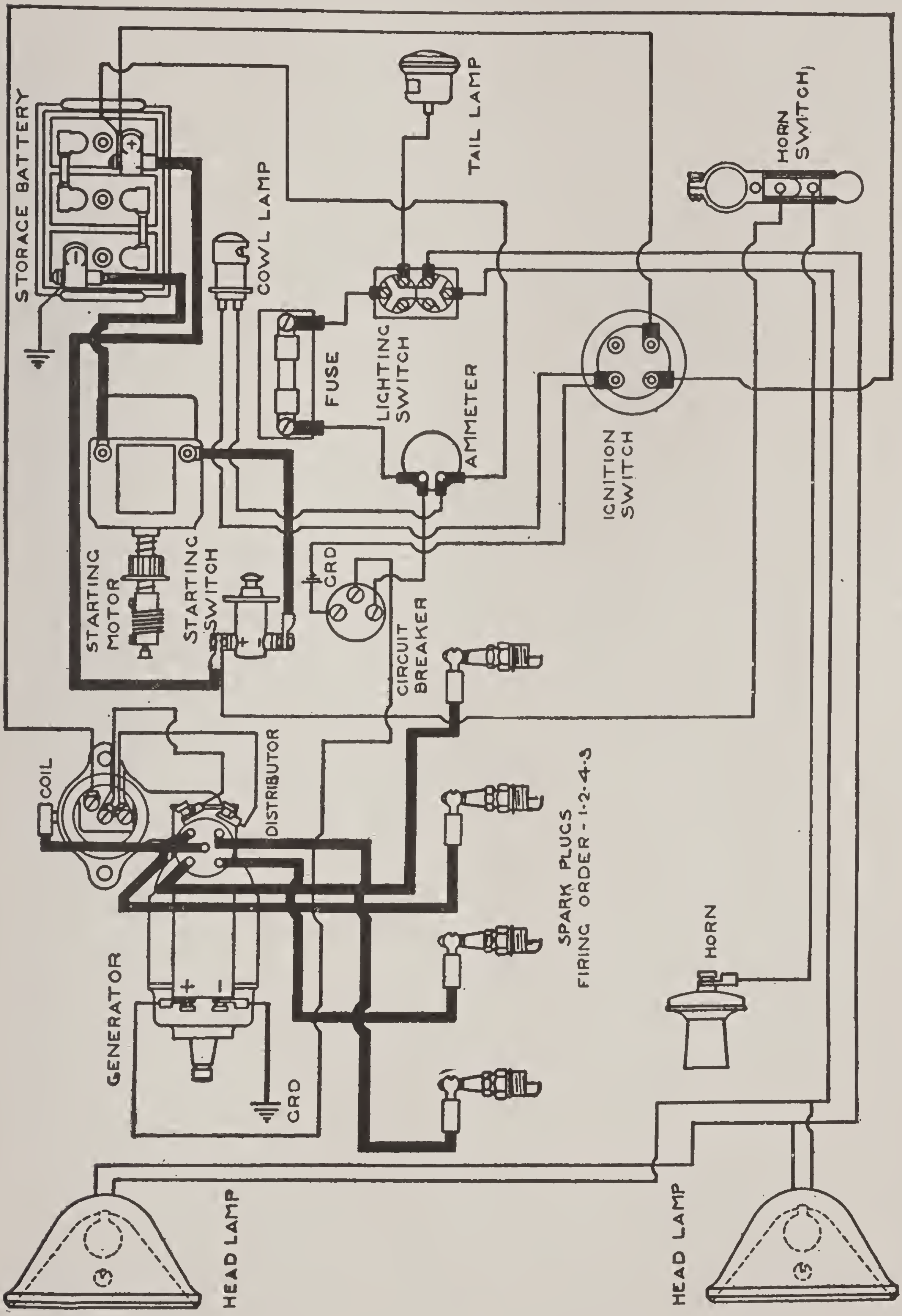


Fig. 209. Wiring Diagram for Auto-Lite System on Chevrolet (Royal Mail and Baby Grand Models) Showing Two-Wire Connections

The wiring diagram, Fig. 209, which is that of the Auto-Lite system as applied to the Chevrolet is of the two-wire type. With

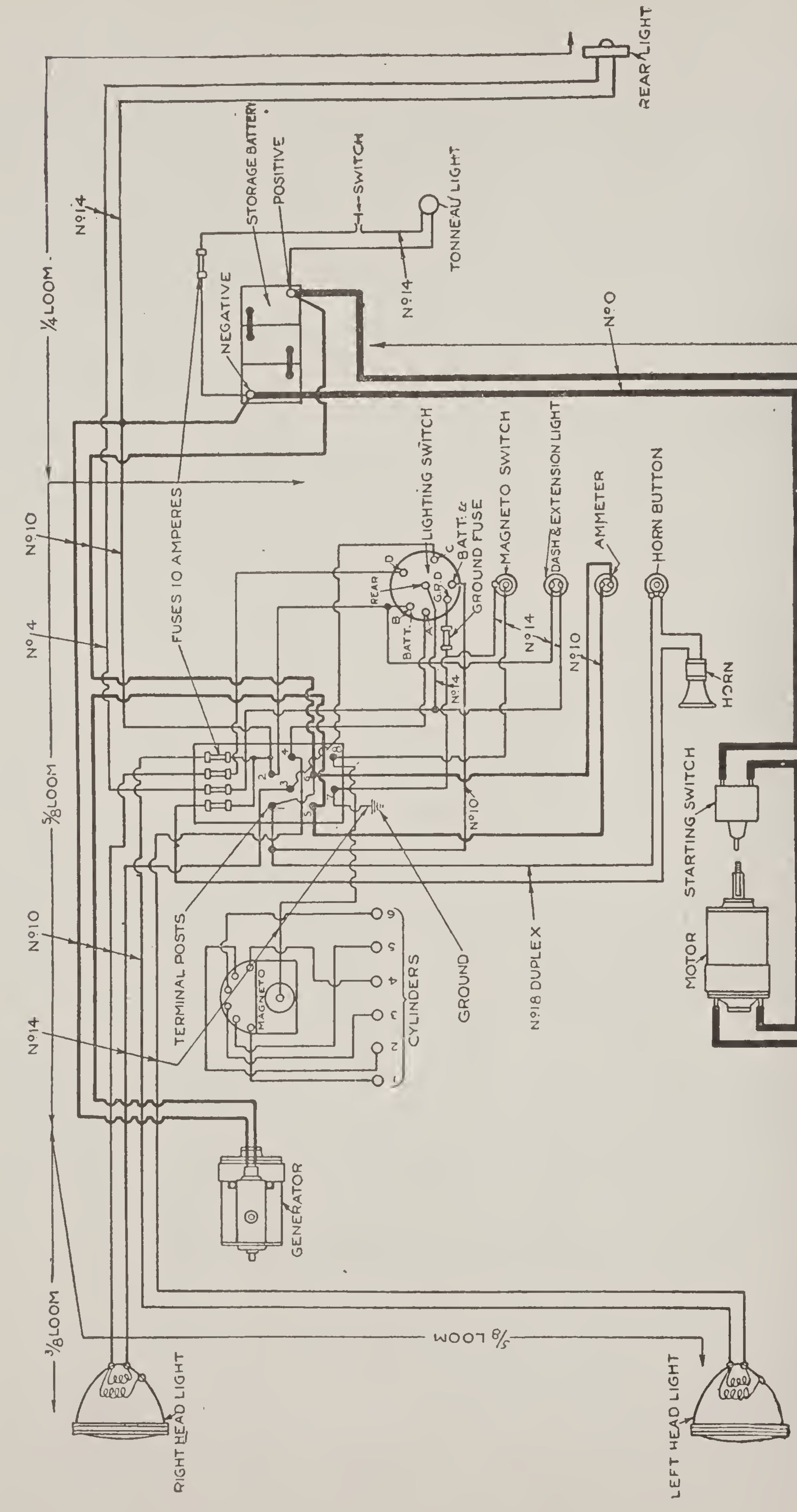


Fig. 210. Wiring Diagram for Bijur Two-Wire System on the Jeffery Chesterfield Six (1916 Model)

the exception of the ignition circuit, which is always grounded owing to the spark plugs completing the circuit by being screwed into the cylinder heads, it will be noted that two-wire connections are made. The ignition circuits are completed by a ground at the battery for the starting current, and by another at the generator for the current when running. The circuit breaker is also grounded.

Jeffery-Bijur Type. The two-wire system of the Bijur as installed on the Jeffery Chesterfield Six is shown in Fig. 210. All lighting circuits are fused and there is also a fuse in the ground connection for the ignition. The numbers referring to the various circuits indicate the proper size of wire used in each circuit. This is an important item in every starting and lighting system, as, where any wires have to be replaced owing to mechanical or electrical injury, they must always be replaced with wire of the same size and character of insulation, as otherwise, further and more serious trouble is apt to follow. Thus, for the starting circuit No. 0 (Brown & Sharpe gage) cable is employed; for the charging circuit between the generator and battery No. 10; for the lighting circuits No. 14, which is the size ordinarily employed for incandescent-lamp circuits in house wiring; and for the horn No. 18. "Duplex" in this connection means that both wires of the circuit are enclosed in the same braided insulation. "Loom" is tubular fireproof insulation through which the wires are passed to afford further protection, and the sizes vary in accordance with the size of the wires.

USE OF PROTECTIVE AND TESTING DEVICES

Circuit Breaker. This is a protective device, the theory of which will be clear at once upon referring back to the explanation of an electromagnet in the introductory chapter. It consists of an electromagnet with a movable armature adapted to open the circuit by its movement, the latter being controlled in turn by the amount of current flowing in the circuit.

By referring back to the diagram, Fig. 208, and noting the particular function of the circuit breaker, an excellent example of the value of ability to trace wiring diagrams at a glance can be shown. Assume that when the button M of the combination switch, Fig. 212, is pulled out, the ignition fails to work. An examination of the diagram shows that when M is pulled out, its lower contact bridges

the wires No. 1 and No. 7 connecting the generator with the battery. At the same time its upper contact bridges a pair of terminals which insert the circuit breaker and the ignition coil on cable No. 8 in the circuit. Further examination of the ignition or lighting circuits shows that throwing on any one of these circuits includes the circuit breaker. The function of the latter is to prevent the discharge of the battery when the generator is standing idle or running too slowly to generate the necessary voltage to charge the battery. It also serves to protect the lamps, ignition coil, and horn from damage, in case any of the wires leading to these essentials should become grounded, and in this rôle takes the place of fuses and fuse block. As it requires 25 amperes to operate the circuit breaker in this particular instance, it is not affected by the normal operation of the lamps, ignition, or electric horn. But in the case of a short circuit or ground, the whole output of the battery would pass through the circuit breaker, moving its armature and breaking the contacts, which open the circuit. This cuts off the current and a spring brings the contacts together again, when the operation is repeated, causing the circuit breaker to vibrate and pass an intermittent current of comparatively small value. While it will not break the circuit on less than 25 amperes, it will continue to vibrate on a current of 3 to 4 amperes. Its continued vibration is an indication that there is a ground in one of its circuits. Hence, no attempt should be made to stop this action by tightening the spring of the circuit breaker, but by locating the ground.

Tracing for Grounds. This can best be done by a process of elimination in which a knowledge of the wiring diagram will come handy. Referring again to Fig. 212, if the circuit breaker operates when switch *M* of the combination is pulled out, it will be apparent that the ground is located in either the main generator-battery circuit, or the ignition-coil circuit, as it will be seen that the lower contact member of the switch throws the former in the circuit and the upper contact member throws the latter in the same circuit with the circuit breaker. If pulling out *M* does not set the circuit breaker operating, but pulling out *T* does, this would indicate a ground in the circuit of the tail and cowl lights, while the operation of the circuit breaker on pulling out either *S* or *H*, would indicate that the ground was located in the wiring of either the side lights

or the headlights depending on which switch caused the circuit breaker to respond. The combination switch B serves to connect the generator and storage battery in the circuit, the same as M, but it also includes the 5-cell dry battery in the ignition circuit. It will be noted that the distributor has six spark plug leads, indicating a 6-cylinder engine, also that the connection of the ignition timer in the circuit is somewhat different from the previous diagram, Fig. 207, in which it is on a branch circuit of the storage battery, whereas in this instance it is also in the generator circuit.

Having determined the particular circuit in which the fault lies it is next necessary to narrow it down to exactly the defection that is causing the ground. For work of this nature nothing handier can be devised than the simple testing set which is described later and which may be assembled at nominal expense.

Fuses. The lighting circuits of many cars are provided with fuses, designed to protect the battery. These fuses are usually of the enclosed type, consisting of a glass tube with brass caps at each end to which the fusible wire is connected, as shown in Fig. 211, Usually when a fuse "blows", due to excessive current caused by a ground or "short", the wire melts entirely and this will be visible. But at times it will simply melt at the soldered connection and not show any fault. In beginning a test it is well to go over the fuses first, holding one of the test points of the lamp circuit on one end of the fuse and touching the opposite end of the fuse with the second test point. Failure of the lamp to light will indicate the defective fuse. On systems employing a circuit breaker as shown in the wiring diagram, Fig. 208, no fuses are necessary as the circuit breaker serves the same purpose and also gives an audible signal of trouble by its buzzing. Upon finding an open circuit where one is supposed to exist as shown on the wiring diagram, it is always well to verify this by again testing the trouble lamp itself before beginning to tear anything out. The rough handling to which such a lamp is subjected frequently causes the filament to break.

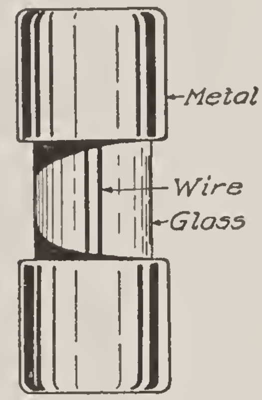


Fig. 211. Typical Fuse

If immediately upon being replaced, a fuse again blows, it may indicate that one of the lamp circuits of the car is short-circuited or the lamp on that circuit is defective, having become short-circuited,

the remedy being a new bulb. In some systems, fuses are used in other circuits, as in the case of the Bosch-Rushmore in which there is a fuse on the switch block to protect the main shunt winding of the generator. The blowing of this fuse indicates a broken battery connection, such as a loose or broken terminal or a corroded battery connection on the cells themselves.

Handy Test Set. Take a porcelain base socket, screw it to a piece of board to form a base. Connect one side of this lamp socket

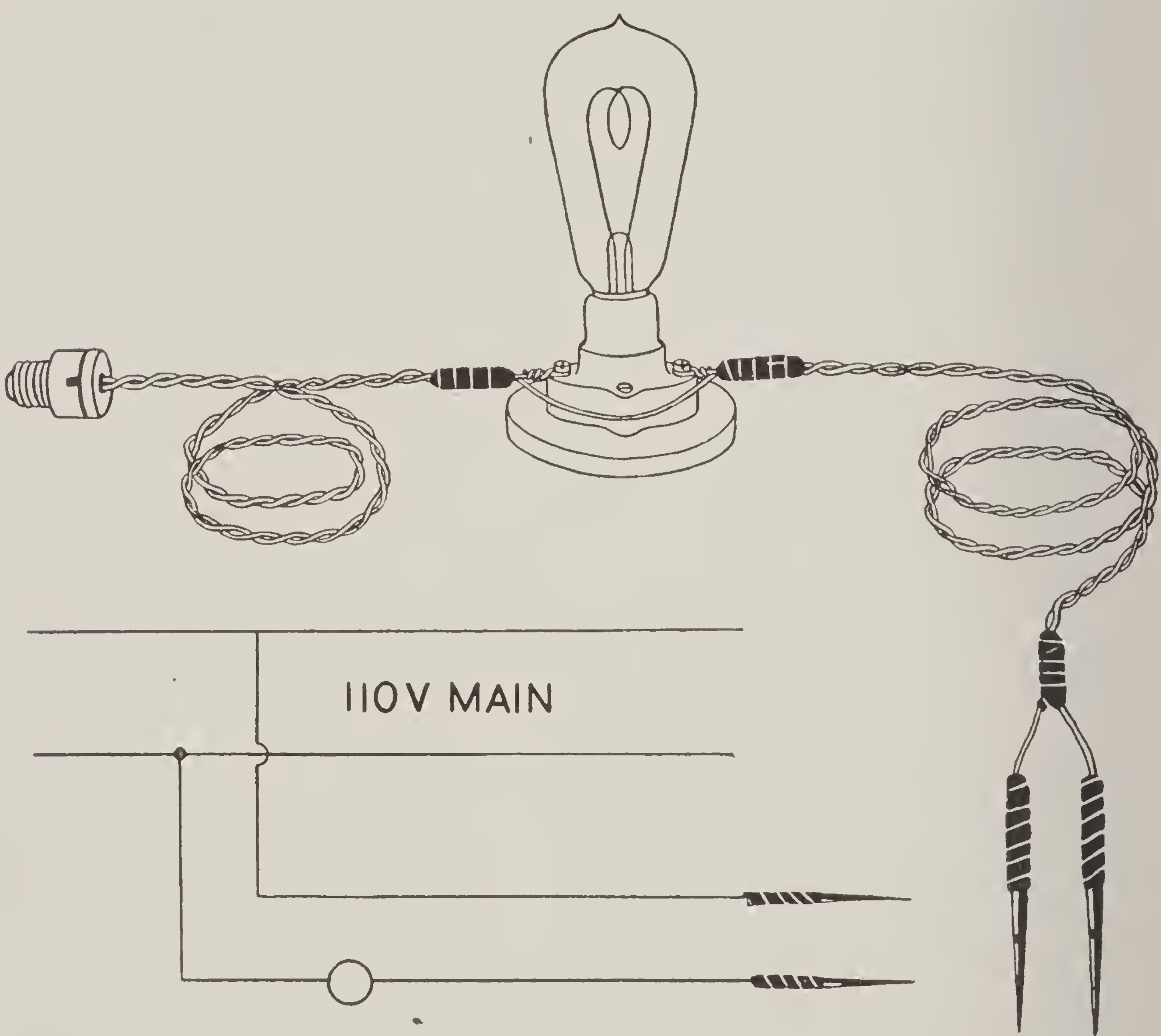


Fig. 212. Handy Testing Set

to a standard screw plug. Procure two pieces of brass or steel rod and file or grind them to a long tapering point. These rods should be about 6 inches long and tapering half their length to a sharp point. Connect the other side of the lamp socket to one of these points and connect the second point to the other terminal of the screw plug. Ordinary lamp cord can be used for the connections. For fastening to the test points it should be bared for several inches, wrapped solidly around the metal rods at their blunt ends, and

soldered fast in place. The joints should be heavily wrapped with tape or covered with other insulating material to form a handle, as shown in the illustration, Fig. 212, As shown by the diagram forming part of this illustration, it will be seen that the lamp is in series with one of the points, but that when the circuit is closed by bringing the two points together, the lamp is in multiple with the main circuit. The lamp should be of the carbon-filament type owing to its greater durability. As a lamp of this type of 16 c-p. only consumes a little over 50 watts at 110 volts, or approximately half an ampere of current, there is no danger of injuring any of the apparatus on the automobile through its use. Sufficient cord should be allowed on either side of the lamp to permit of connecting it up with the outlet conveniently.

In using this test outfit, the two test points are pressed on places between which no current should pass, and if the lamp lights it indicates that there is a ground between those points. For example, in Fig. 208, if there were a ground between the generator and the switch so that no current reached the latter, the lamp would not light when the test points were placed on terminals 1 and 7 of the diagram, the generator then being in operation. But a little searching along this circuit would soon show where it was grounded, thus making it easy to locate the break or ground. Fig. 213 is a graphic illustration of a ground causing a short circuit, due to worn insulation. Much more satisfactory results can be obtained with a test set of this nature than with either an expensive hand ringing magneto test set, or with a set consisting of a bell or buzzer and a few dry cells. The former is unnecessarily expensive for the purpose while the latter has not sufficient potential to force the current through grounds or breaks that present too great a resistance, whereas the higher voltage of the lamp test set will cause it to give an indication where the battery set would not. With the aid of such a set, every circuit shown on even the most complicated of

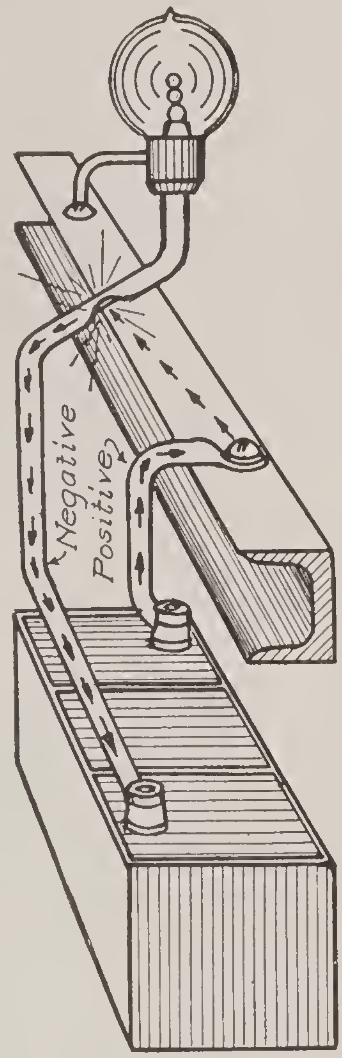


Fig. 213. Diagram of Ground or Short Circuit
Courtesy of Gray and Davis Company

wiring diagrams can be tested in fifteen to twenty minutes, maybe less, depending upon how accessible the connections of the various circuits happen to be.

If preferred, owing to greater convenience, a 6-volt lamp can be used in the socket of the test set and current from the car battery can be utilized for testing. In case the car happens to have either a 12-volt or a 24-volt system, connect lamp terminals to but three of the cells. Should the lamp not light to full incandescence it

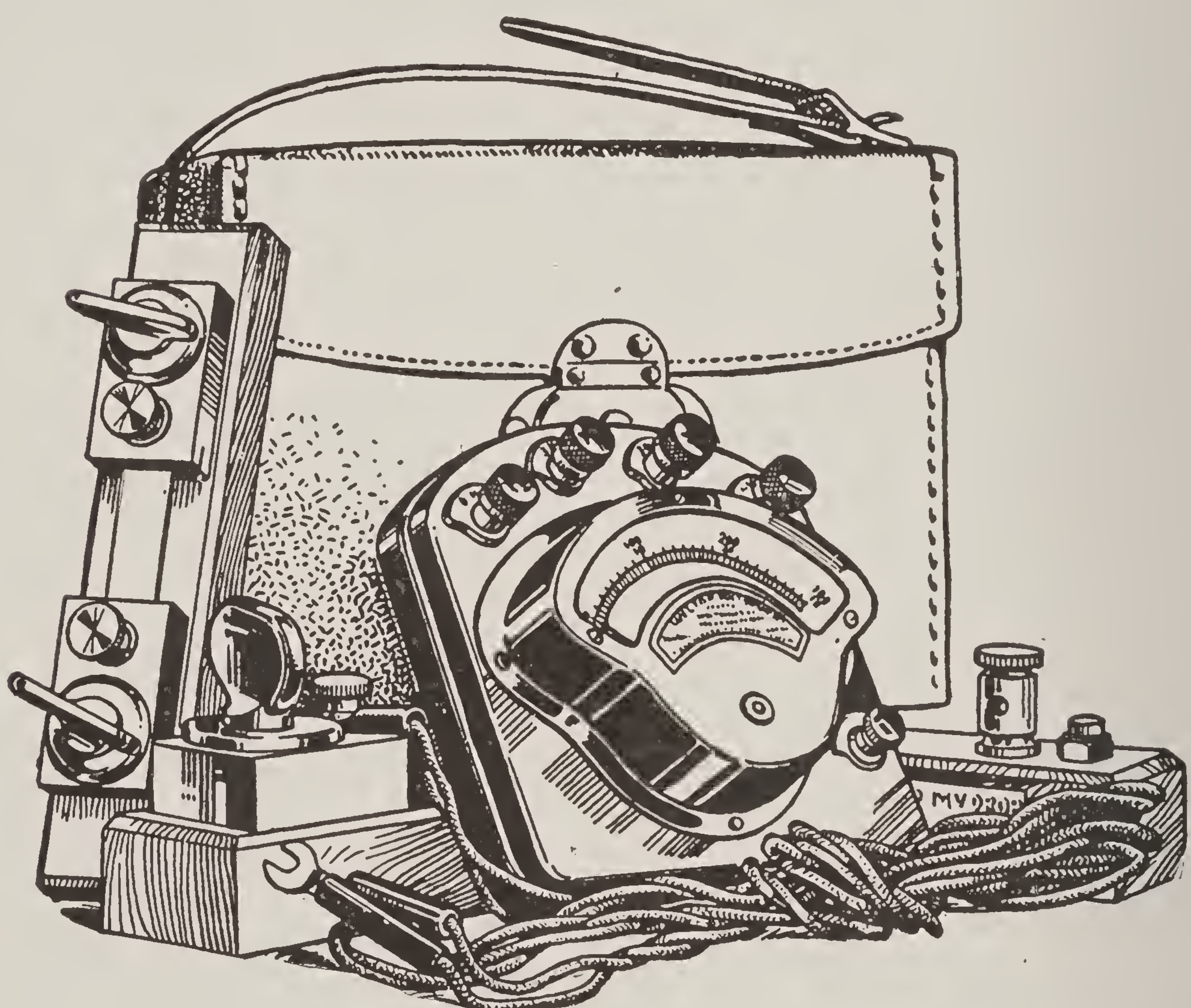


Fig. 214. Portable Combination Volt-Ammeter for Testing

will indicate a weak battery. Full directions for the care of storage batteries are given in the résumé in Questions and Answers, and also in the article on Electric Automobiles. In case the battery does not respond to any of the ordinary methods of treatment given there, it will usually be found preferable to refer it to the nearest service station of the battery manufacturer. This is particularly the case where after refilling with distilled water to the proper level and slowly recharging, the battery does not increase in voltage and specific gravity reading with the hydrometer.

Always Test the Lamp. Whether a standard 110-volt lamp or one of the 6-volt type (for which an adapter may be necessary to fit the standard socket) is used, it is a good precaution always to test the lamp itself before going over the wiring on the car. This will avoid the necessity for blaming things generally after failing to find any circuit at all—after fifteen miutes of trying everything on the car—due to the lamp having a broken filament or one of its connections having loosened up.

Special Testing Instruments. For the garage that claims to be fully equipped to give all necessary attention to the electrical system of the modern car, something more than the simple lamp testing outfit is necessary. Portable volt-ammeters such as shown in Fig. 214 are made specially for this purpose. This is a Weston combination volt-ammeter, the voltmeter being provided with a 0–30, 0–3, and 0 to $\frac{1}{10}$ scales for making voltage tests, together with three shunts having a capacity of 0–300, 0–30, and 0–3 amperes, respectively, which are used in connection with the $\frac{1}{10}$-volt scale for making current measurements. A special set of calibrated leads for use with these shunts is also provided. With the aid of such an outfit, accurate tests can be made covering the condition and performance of every part of a starting-lighting and ignition installation. For example, a starting system may be otherwise in perfect working condition, but its operation causes

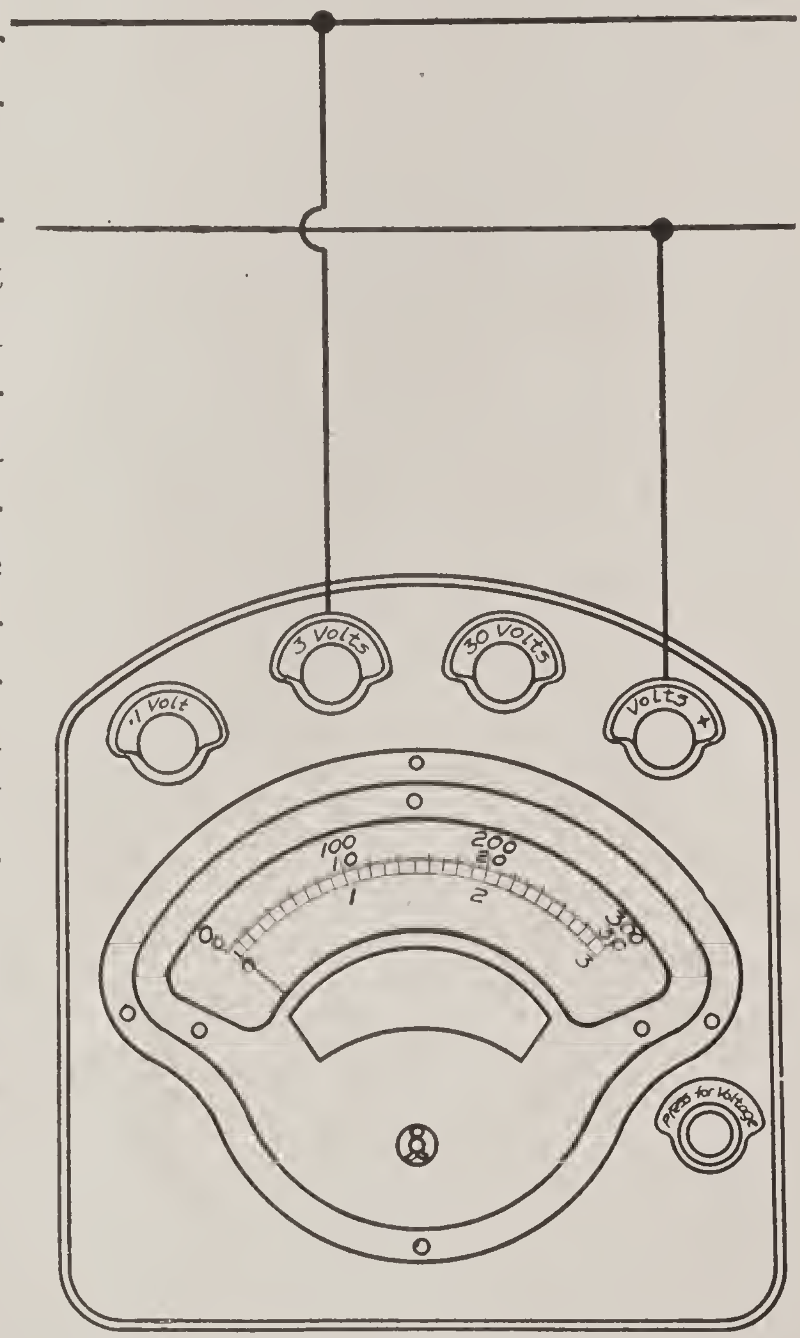


Fig. 215. Diagram Showing 3-Volt Scale Connected across a Circuit

such an excessive demand on the storage battery that the generator is not capable of keeping the latter sufficiently charged. Generator tests, which are described later, having failed to show anything wrong with the dynamo, a test of the starting motor, using the 0–300-ampere shunt of the instrument would doubtless show that an unnecessarily large amount of current was being demanded by the motor for its operation, and indicate a fault in the latter.

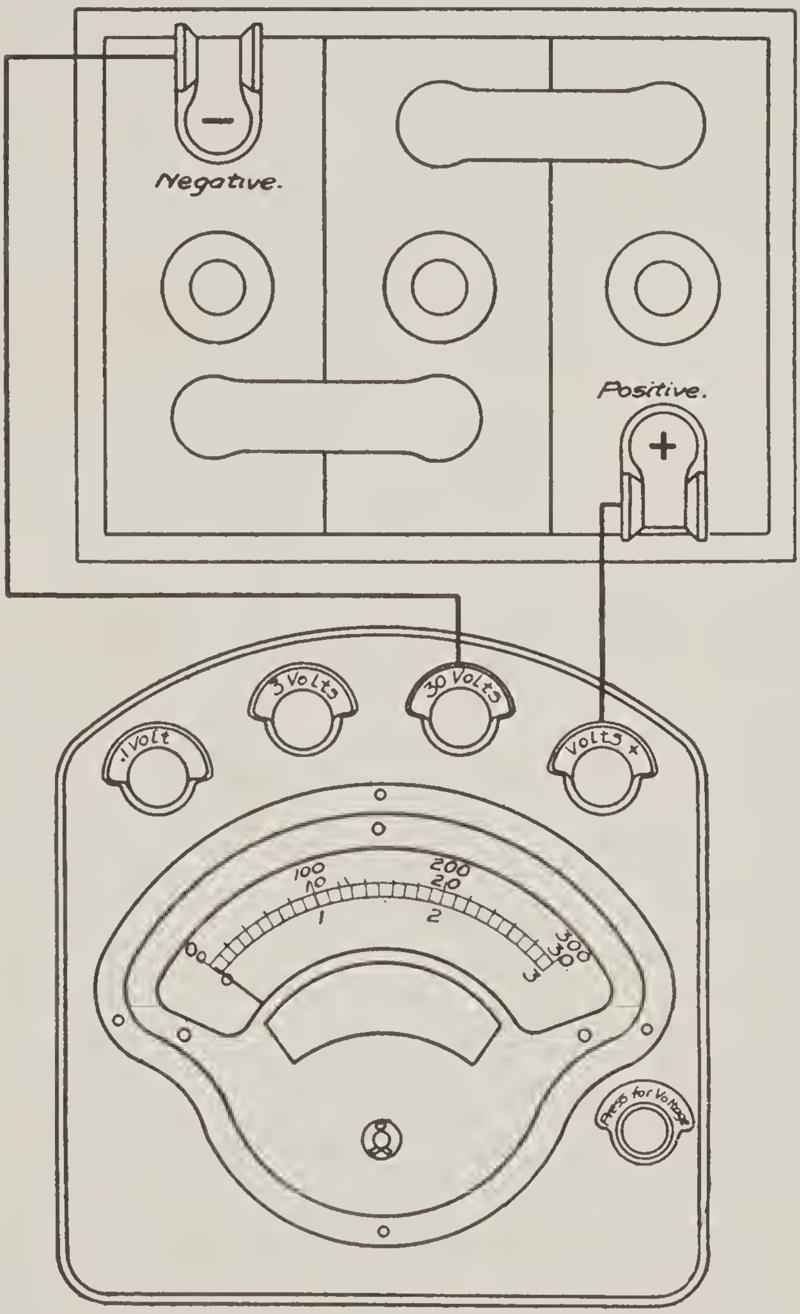


Fig. 216. Diagram Showing 30-Volt Scale Connected across Storage Battery Terminals

Voltage Tests. When the instrument is used as a voltmeter it is necessary to select the proper scale for the circuit, and if there is any doubt it is well to start with the 30-volt scale. For testing individual cells of the storage battery the 3-volt scale would naturally be used, while for testing the entire battery, the 30-volt scale would be the proper one to apply. The proper method of connecting the voltmeter to the circuit is shown by the diagrams, Figs. 215 and 216. It is necessary to connect the positive side of the meter to the positive side of the circuit and the other terminal to the negative. Where the polarity of the circuit is not known, this can be readily determined by a trial reading. If the pointer moves to the right, the connections are properly made; in case it moves to the left, it will be necessary to reverse the connections, which should be done at the circuit terminals and not at the meter, to avoid any accidental short circuits.

Ammeter Readings. When using the ammeter to determine the amount of current consumed by any of the apparatus, such as the starting motor or the lamps, it is necessary to first select the proper shunt. Should the value of the current to be measured be unknown, it is well always to start with the 300-ampere shunt

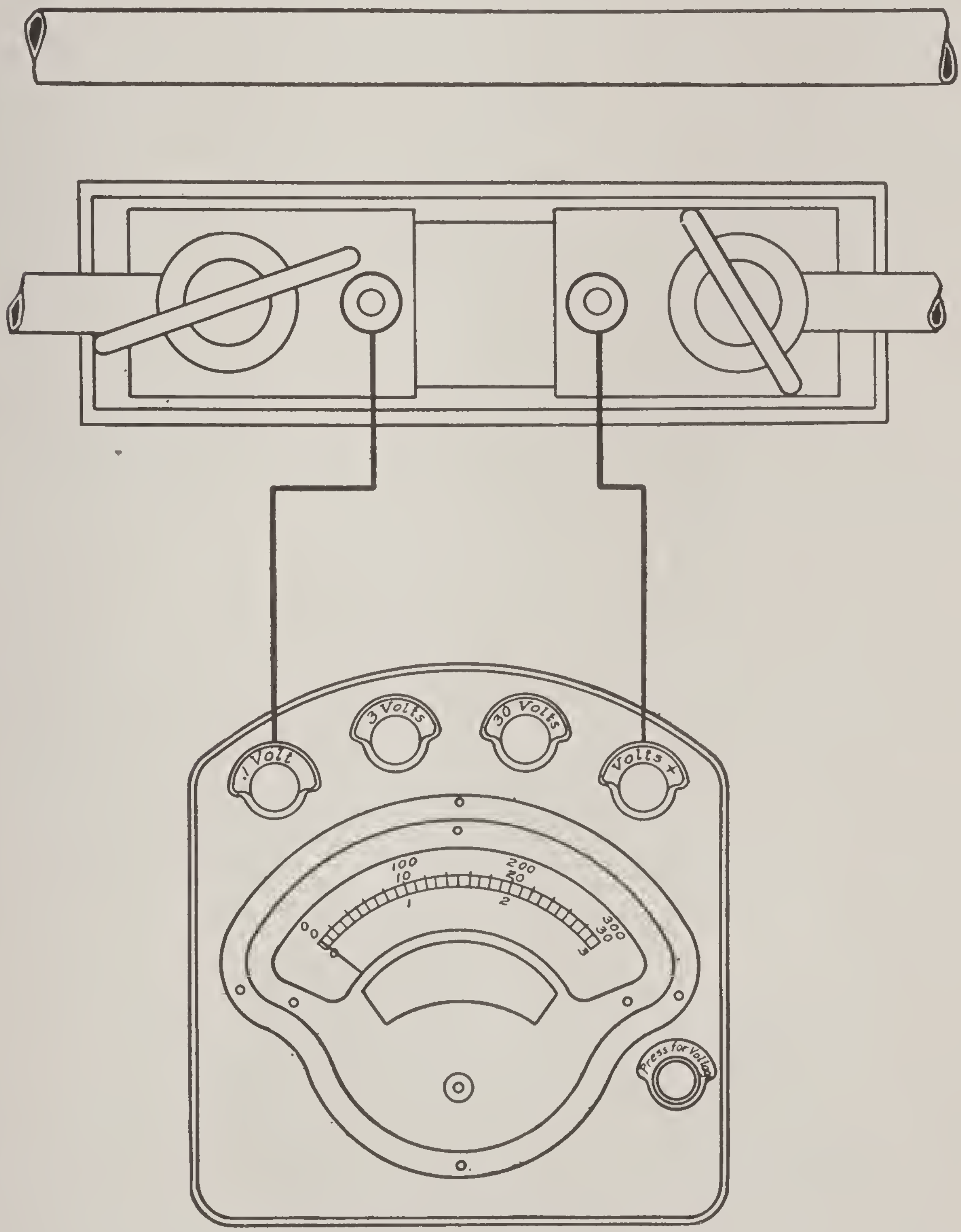


Fig. 217. Diagram Showing Method of Connecting Ammeter to 300-Ampere Shunt

and then insert the 30-ampere shunt in case the reading shows the current to be less than 30 amperes. These shunts are connected in the manner shown by Fig. 217, and as will be plain from this diagram, all shunts are connected in the circuit in a similar manner. The connections always remaining the same, it is only necessary

to substitute the different shunts as required by the circuit to be measured. If the polarity be reversed, it is only necessary to shift the connections from the ammeter to the shunt which should be done at the latter, there being no necessity to change the connections of the shunt itself to the circuit. The 300-ampere shunt must always be used for measuring the starting current, as the latter will rarely have a value of less than 200 amperes when the switch is first closed owing to the necessity of exerting great power at first to overcome the inertia of the gasoline engine, particularly at a low temperature when the lubricating oil has become gummed. Cables of the same size as those employed on the starting-motor circuit of the car should be provided for connecting up the shunt to make the tests. The 30-ampere shunt is employed for measuring the charging current to the battery, while the 3-ampere shunt is used for the individual lighting circuits or for the primary ignition current.

In the following section, the various systems in general use are described in detail.

AUTO-LITE SYSTEM

Six-Volt; Two-Unit; Single Wire

Generator. Three types of generators are furnished. One has a permanent magnetic field and resembles a magneto but can

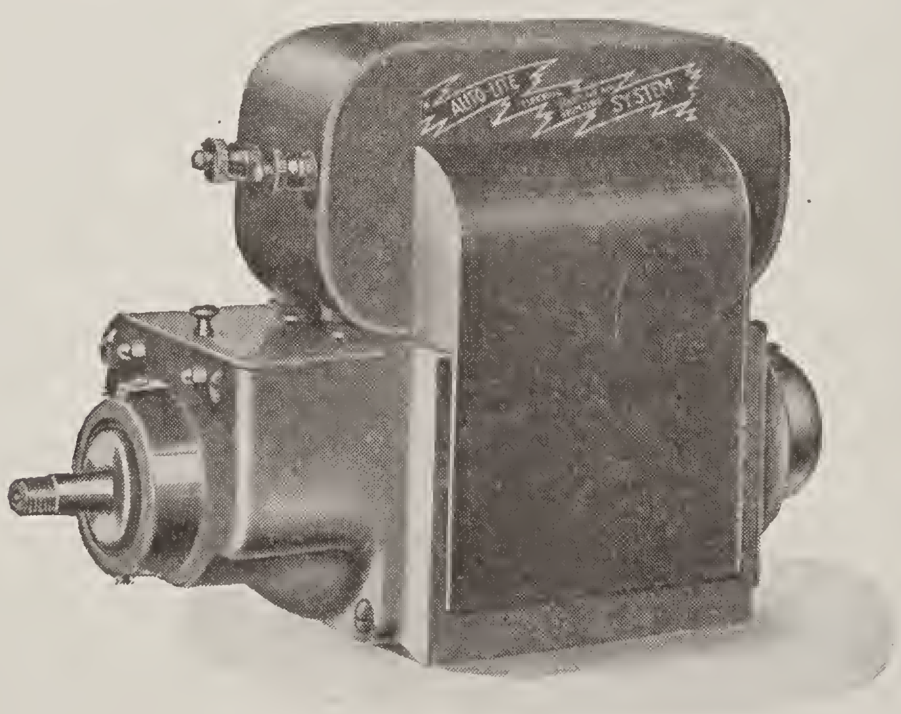


Fig. 218. Auto-Lite Generator of the Bipolar Type
Courtesy of Electric Auto-Lite Company, Toledo, Ohio

be distinguished by its drive and governor, as well as the fact that it is fitted with a commutator and brushes instead of a contact

breaker and distributor. It has been supplied chiefly for installation on cars which were not originally fitted with electric lighting and starting systems. The second is somewhat similar in design but has an excited field, the field magnets being of U-form and laminated; this type of generator is used on the Overland Model 82. There is a single field winding, as shown in Fig. 218. The third is a four-pole machine having two wound poles, usually termed *salient* poles and two *consequent* poles, which carry no windings. A diagrammatic section of this generator is shown in Fig. 219. The salient poles are those in the vertical plane while the consequent poles

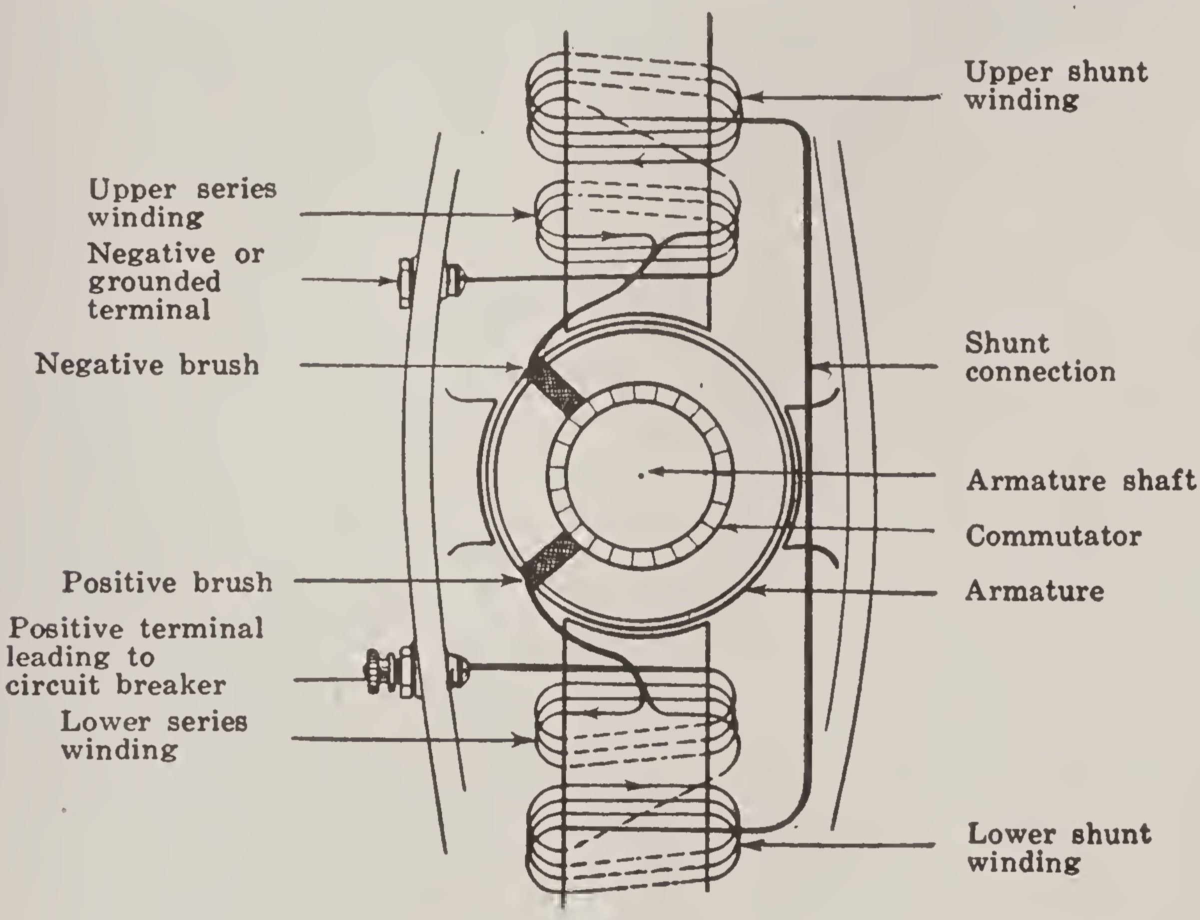


Fig. 219. Diagrammatic Section of Four-Pole Auto-Lite Generator

are horizontal. The diagram also shows the commutator, brushes, and the compound winding of the generator.

Regulation. The current output of the permanent-field type is regulated by a centrifugal governor; it should not drop below 10 amperes, nor exceed 12 amperes. Any falling off can be remedied frequently, simply by cleaning the governor out thoroughly with gasoline, allowing it to dry, and giving it a drop or two of light oil; if this does not increase the output sufficiently, the weights can be moved inward an eighth of an inch or more to decrease the pressure on the springs mounted in the governor arms, Fig. 220. This per-

mits the generator to run at a higher speed. The regulation of the other type is *inherent* and is due to the series windings of the field being made in the reverse direction to that of the shunt windings, so that their polarity is reversed. This is commonly referred to as a *bucking coil,* also as a differential winding. As the speed increases, the magnetizing effect of the shunt coils is opposed by this bucking winding and thus kept within safe limits. This type of generator is used on the Overland Model 80 and Model 81, besides other cars.

Fig. 220. Governor of Auto-Lite Permanent-Magnet Type Generator

Starting Motor. The starting motor is a series-wound multipolar type having four salient poles, Fig. 221 (used on Overland Model 80 and Model 81). In this type the switch is combined directly with the motor, being mounted in a housing at the left end as shown in Fig. 221. It is also fitted with a special locking device, the details of which are illustrated in the sectional view, Fig. 222. One of the buttons on the control board on the steering column closes the circuit of the solenoid shown in this illustration; this causes the plunger to lift and release what is known as the *gear-latch.* The shaft carrying the switch also serves to shift the pinion on the end of the starting-motor shaft into mesh with the flywheel gear. A later and more widely employed type of Auto-Lite starting motor is shown in Fig. 223; this is installed on the Overland Model

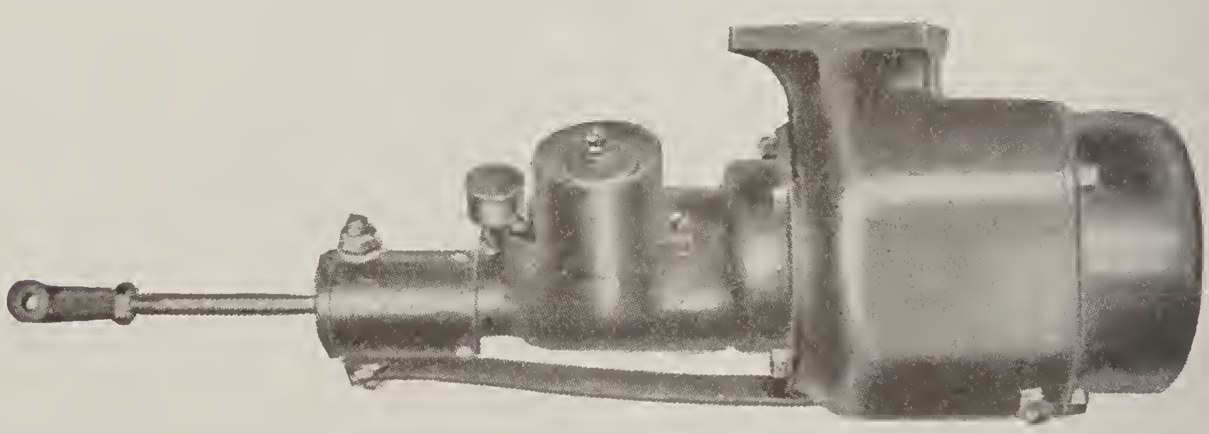


Fig. 221. Auto-Lite Starting Motor Used on Overland Models 80 and 81

82 besides a number of other cars. It is known as the *Bendix drive* and is coming into very general use owing to its simplicity and its

automatic operation which eliminates the necessity for gear-shifting devices actuated by the switch, when operating the starting motor.

The armature shaft has a threaded extension provided with an

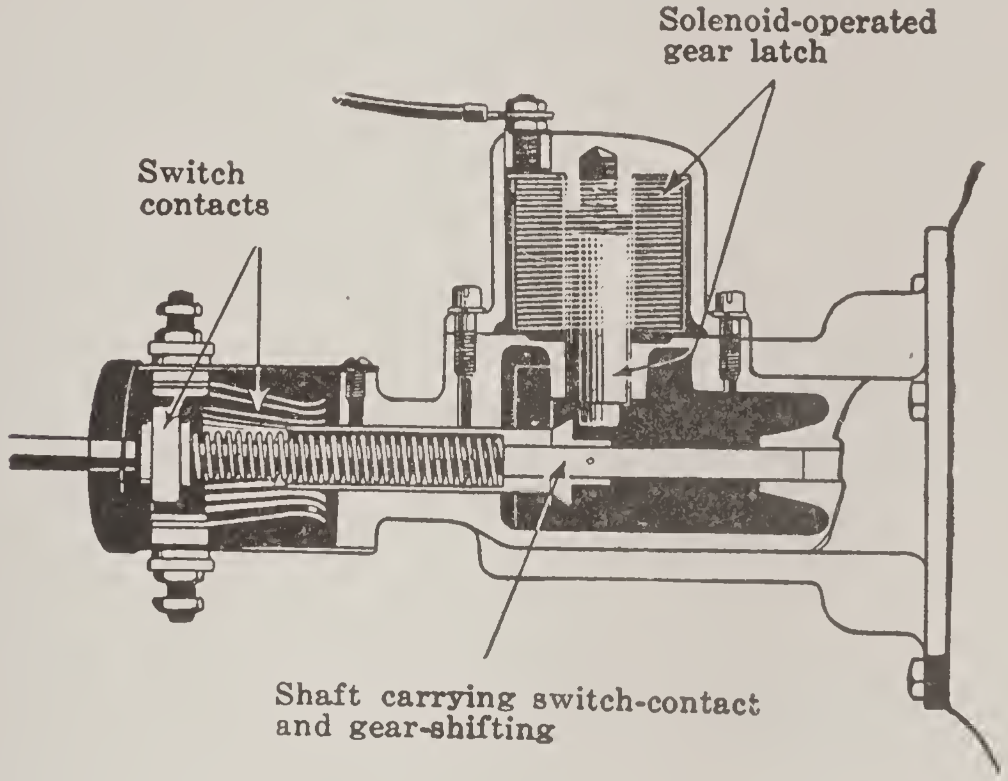


Fig. 222. Sectional View of Auto-Lite Starting Switch and Gear Release

outer bearing and carries a pinion. A weight is solidly attached to this pinion and the latter is loose enough on the shaft always to

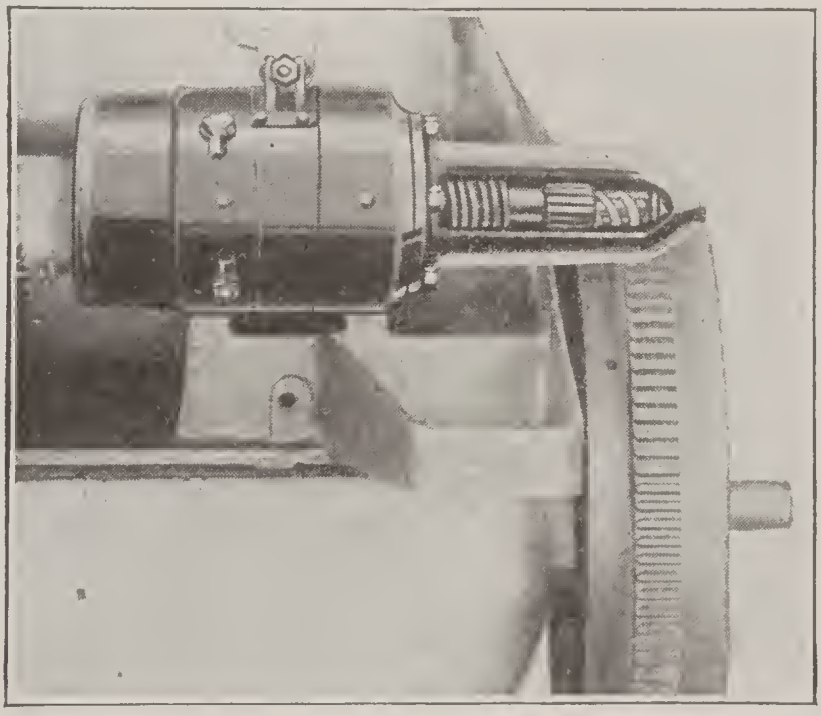


Fig. 223. Auto-Lite Starting Motor with Bendix Drive

occupy the position shown with the weight underneath when the shaft is idle. The leading screw has a triple thread. On starting the electric motor the inertia of the weight causes it and the pinion

to be carried along the shaft and into mesh with the gear on the flywheel in which relation it remains until the engine begins to run under its own power. This reverses the relation, the flywheel then driving instead of being driven, which automatically throws the pinion out of mesh. The coil spring shown is simply to take up the shock of starting and permits a slight play between the motor shaft and the threaded extension. Before the switch which is located on the footboards can be operated, a button on the control board must be pushed. This actuates a solenoid the plunger of which raises a latch, releasing the starting switch.

Battery Cut-out. The battery cut-out is shown in Fig. 224. As already explained, the majority of electric systems on the automobile must be provided with a cut-out to protect the battery when the generator speed falls below a certain point. It is frequently referred to as a *circuit breaker,* which it is in fact, though the circuit breaker is a protective device used for another purpose, as has been mentioned. The cut-out may be compared to a check valve in a water supply line between a pump and a tank; the pump can force water into the tank against its pressure but, regardless of how great this pressure becomes owing to the filling of the tank, the water cannot run back through the pump when the latter is idle.

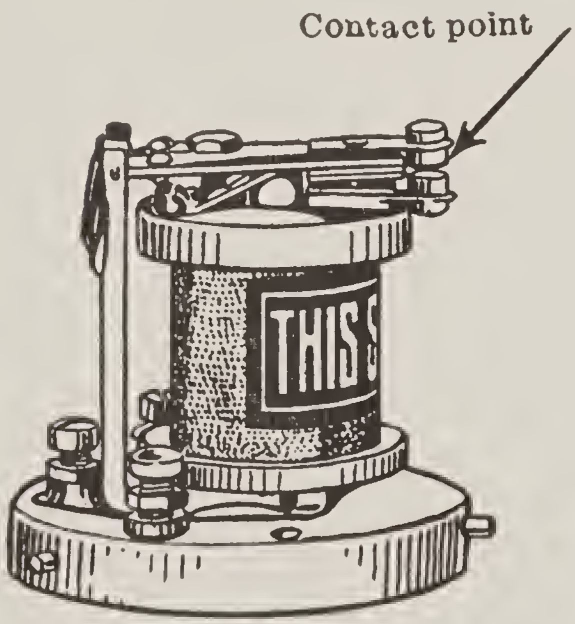


Fig. 224. Auto-Lite Battery Cut-Out (Circuit Breaker)

In principle, the battery cut-out is simply a magnetically operated switch. When the current passes through its winding the armature is attracted and brings a pair of contact points together. These will be seen at the upper right hand at the point of the arrow. In the best-grade apparatus, these points are of platinum or platinum and iridium as the latter is proof against oxidation as well as corrosion and resists pitting under the electrical current better than any other metal. As it costs more than gold, silver, which is next best for the purpose, is frequently employed. The cut-out in this case is set to close the circuit and allow the generator to charge the battery when the engine is driving the car at $7\frac{1}{2}$ miles per hour, but

when the speed is dropping it does not open the circuit until it falls to 6 miles per hour. This is to prevent the cut-out from operating continuously when the car is running at its opening speed of $7\frac{1}{2}$ miles. The battery, however, governs to a large extent the running speed at which the cut-out will operate. When fully charged, owing to the higher resistance thus presented, the cut-out does not close the circuit until the car is running at 10 to 12 miles per hour. In case the cut-out is removed from the car for any reason, the latter must not be operated until a short piece of bare copper wire is securely connected from the wire terminal post of the generator to one of the brass screws in the name plate.

Instruments. The instrument regularly supplied is a double-reading ammeter showing *charge* and *discharge* from 0 to 15 amperes. When lamps are off with car running at 10 miles per hour or over, it should indicate *charge.*

Wiring Diagram. The connections are practically the same, regardless of the type of starting motor installed, so that the following description will cover all three of the Overland models mentioned, Fig. 225. The ignition system is entirely independent of the starting and lighting system, although it appears on the diagram. The connections are as follows: Cable 12072, battery negative to motor terminal; cable 12073, battery positive to starting switch; wire 12236, starting switch to fuse block; wire 12066, fuse to positive ammeter terminal; wire 12066, negative ammeter terminal through fuse; wire 12069, to battery cut-out; wire 12068, generator positive terminal to cut-out. The battery negative is grounded at the end of cable 12072, while the cut-out is grounded to the frame through the wire 12906 and the generator is grounded at its negative terminal. This is an example of the frame of the car being employed for the negative side of the circuit, as compared with the Gray & Davis in which it is utilized for the positive side. While the ground connections of the lamps and horn are indicated as separate wires, in the case of the lamps the socket itself forms the ground connection. The location of the various fuses and the relation of the various essentials of the system will be clear upon tracing the diagram.

Instructions. While a car never comes into the shop to have its electrical equipment examined until some fault develops, and

the man who has to locate the trouble seldom has occasion to run the car in ordinary service, still it is important that he should famil-

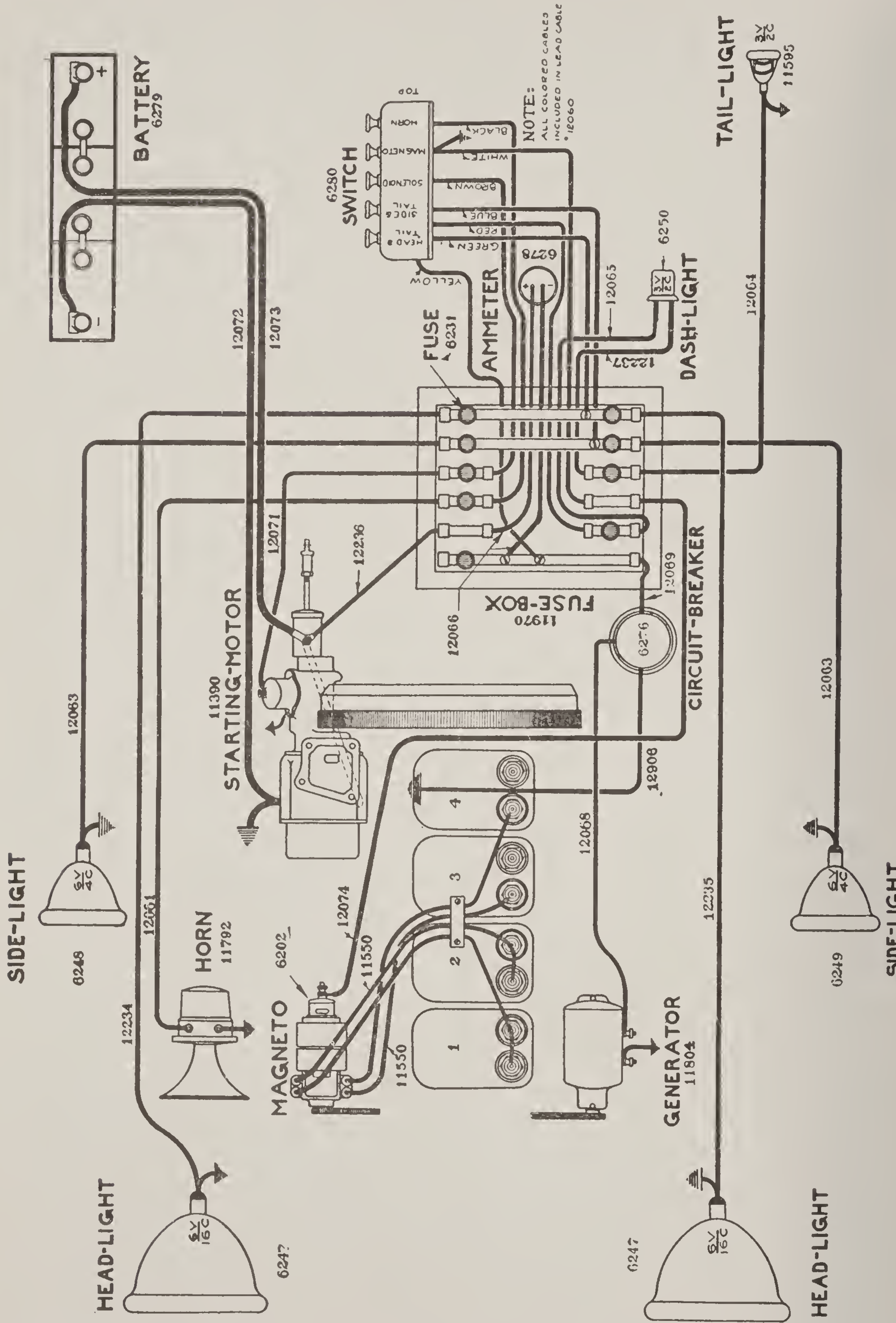


Fig. 225. Auto-Lite Wiring Diagram for Overland Cars

iarize himself with the instructions issued to the owner, in order that he may know at a glance whether these instructions have been

carried out or not. It is safe to say that more than half the troubles that arise with this equipment are due to failure to follow instructions in its use. The average motorist ordinarily pays little attention to the workings of the apparatus until it goes wrong and then he is helpless. There is, however, another type—the man who is given to tinkering. He is responsible for not a few of the problems that come into the garage, and familiarity with the manufacturer's instructions will assist in tracing the result of his efforts.

Chain Drive. The silent-chain drive of the generator should be inspected occasionally and any slack taken up by loosening the screw which holds the generator on its bracket, and moving the generator over by means of the adjusting screw. The chain should be just slack enough to have no strain on its links when the engine is not running. Although the initial stretch of the chain is taken out at the factory by running it under load, these chains will continue to stretch slightly in service. After making the adjustment the holding screws should be re-tightened.

Commutator and Brushes. The commutator is the most vulnerable part of a direct-current machine. It should be examined first whenever there is any trouble with the generator, such as insufficient output of charging current, or with the starting motor, such as loss of power, the battery being in good condition. (No mention is made of battery instructions in this connection as the subject is fully dealt with in another volume, and in the summary following this section. The battery is, however, the cause of fully 80 per cent of all electrical-system troubles and neglect is at the root of most of these.)

The commutator is made accessible by the removal of a small plate—in this case, the name plate. If it is blackened and rough, the brushes first should be examined and trued up and the commutator should be smoothed down with fine sandpaper (never use emery cloth as it is metallic and will short-circuit the segments). The mica insulation should be carefully examined; if it is flush with the copper segments this is the cause of the roughened up brushes, and the mica should be undercut. Detailed instructions for smoothing the commutator, truing up the brushes and undercutting the mica insulation are given in connection with the Delco system. Any carbon dust from the brushes should be carefully blown out

as this will tend to short-circuit the armature and field windings. See that the brush holders swing easily on the studs and that there is just enough spring tension on the brushes to make good contact on the commutator. Too much tension will cause unnecessary heating and wear of the commutator and brushes. Keep the commutator and brush chamber free from dirt and grease. Never replace brushes with any but those supplied by the manufacturer. See that the brush holders are well insulated from their supports, replacing any of the insulating plates, bushings, or washers that may have become damaged. Should the battery or generator be disconnected do not run the engine until they are again connected. Should it be necessary to do so, connect a short piece of bare copper wire from the terminal of the generator to one of the brass screws in the name plate.

Generator Tests. The following tests will be found an aid in locating failure of the generator.

Field. To test the field coils, lift the brushes off the commutator and insert a piece of fiber or clean dry wood. Close the battery cut-out by pressing the finger on the contacts. The ammeter should then register about one ampere if the coils are all right.

Armature. To test the armature, remove the driving chain and close the cut-out as before. This will *motorize* the generator and it should then run at 650 to 750 r.p.m., drawing 3 to 3½ amperes, if its windings are in good condition. This refers to the generator on Overland Model 80 and Model 81. The Model 82 generator should run at 275 r.p.m. on a current of 2 to 2½ amperes.

Grounds. Tests for grounded windings in either the field or armature coils can be carried out with the aid of the testing-lamp outfit described. Remove the brushes, place one test point on a commutator segment and the other point on the armature shaft; if the coil is all right the lamp will not light. Each coil can be tested in succession in the same way. To test the field coils, lift one brush from the commutator and place the test points one on each brush holder; the lamp should light as this places the field coil in series with the lamp.

In case any faults are located in the windings it will usually be found advisable to consult the manufacturer's service station

or the factory direct, as either armature or field winding is something that is beyond even the best equipped of garages.

Battery Cut-Out Tests. Failure of the battery cut-out to operate will most frequently result from pitted or blackened contact points. Clean and true up with fine sandpaper which should be drawn back and forth between them while slight pressure is applied to the upper one, taking care to keep the sandpaper at right angles to the vertical plane of the points, as otherwise they will be put out of true. See that the faces of both points come together over their entire surface when pressed together with the finger.

Operation. Test for operation by sending the current from five dry cells in series through the coil of the cut-out. The points should come together with a snap as soon as the circuit is completed and should hold fast as long as the current is on. This test should not be continued too long, however, as the dry cells will weaken. In case the armature is not attracted, leaving the points in the open position when the battery current is sent through it, inspect the connections from the binding posts to the coil. The wire is small and may have broken from vibration.

Should no circuit be found through the coil with the dry battery, try the test-lamp outfit on the 110-volt circuit, holding one point down on a binding post and just touching the other momentarily with the second point. If the lamp fails to light, there is a break in the coil and the cut-out should be returned to the manufacturer.

BIJUR SYSTEM

6-Volt; Two-Unit; Single- or Double-Wire, According to Make of Car. Also 12-Volt; Single-Unit

Generator. The generator is a special reversible type. Due to the reversible characteristics of the machine it may be connected in either direction and it will assume the proper polarity for charging the storage battery.

Regulation. This is the constant-voltage type, the regulator and battery cut-out being mounted directly on the generator. The principle of this method of regulation is to maintain the voltage of the generator constant, the current output depending on the resistance of the circuit and varying with the state of charge of the battery. This is accomplished by the use of a magnetic vibrator

similar in principle to the ordinary electric bell, or buzzer, though it takes a different form, Fig. 226. *H* is the magnet winding, *A* the soft-iron core of the magnet, and *G* the vibrating armature. To prevent *G* from coming directly in contact with the pole piece on the upper end of *A*, a stop pin *I* is provided. *C* and *F* are the contacts, *C* being held against *F* by the tension spring *E* and is pulled away from *F* by the magnetic pull of coil *H* in armature *G*. These contacts are mounted on vibrating reeds (thin strips of spring brass) placed at right angles to each other. Contact *C* and its reed are attached to the armature *G*, and stop pins *B* limit the lateral movement of this contact. *F* and its reed are also mounted on an arm as shown.

When a current flows through the magnet coil the armature *G* is attracted, automatically released by the breaking of the circuit, and again attracted so that it vibrates, the rate of vibration depending upon the amount of current. As the vibrator is included in the field circuit the current in the latter is accordingly pulsating, and as a field circuit, owing to its heavy iron core has considerable self-induction, the amount of current flowing through it will decrease in proportion to the rapidity of the vibration or pulsations. To prevent the field losing its excitation altogether every time the vibrator opens the circuit, the latter is not connected directly in circuit with the shunt winding of the generator, but is placed across the terminals of a resistance unit in series with the shunt field. This also prevents the arcing or heavy sparking that otherwise would result from the breaking of a circuit having so much inductance. Failure of a vibrating regulator is usually caused by the contact points sticking or fusing together owing to the heat. Mounting the points on reeds is designed to prevent this as the vibration due to the operation of the car keeps them moving laterally, thus overcoming the formation of a cone of metal on the negative contact point caused by the small particles transferred from the positive.

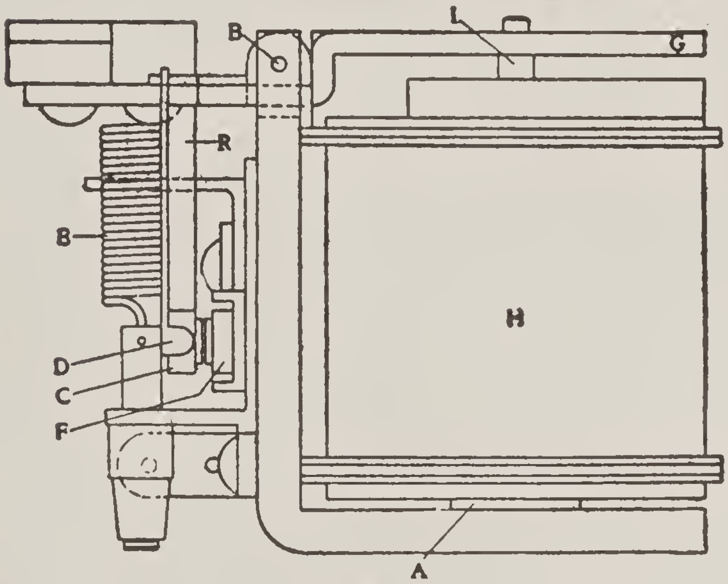


Fig. 226. Bijur Vibrator Voltage Regulator
Courtesy of "The Horseless Age"

Starting Motor. This is of the series-wound multipolar type. The installation of motor and starting switch as mounted on Hupp cars is shown in Fig. 227.

Instruments. A dash ammeter is supplied. With constant voltage control the amount of current delivered to the battery by the generator depends upon the condition of the former. With battery almost discharged, its voltage is lowered and the current reading may then be as high as 15 to 20 amperes. With battery fully charged and no lights on, the reading will decrease to 5 amperes or less, the charging current at all times depending upon the state of charge of the battery.

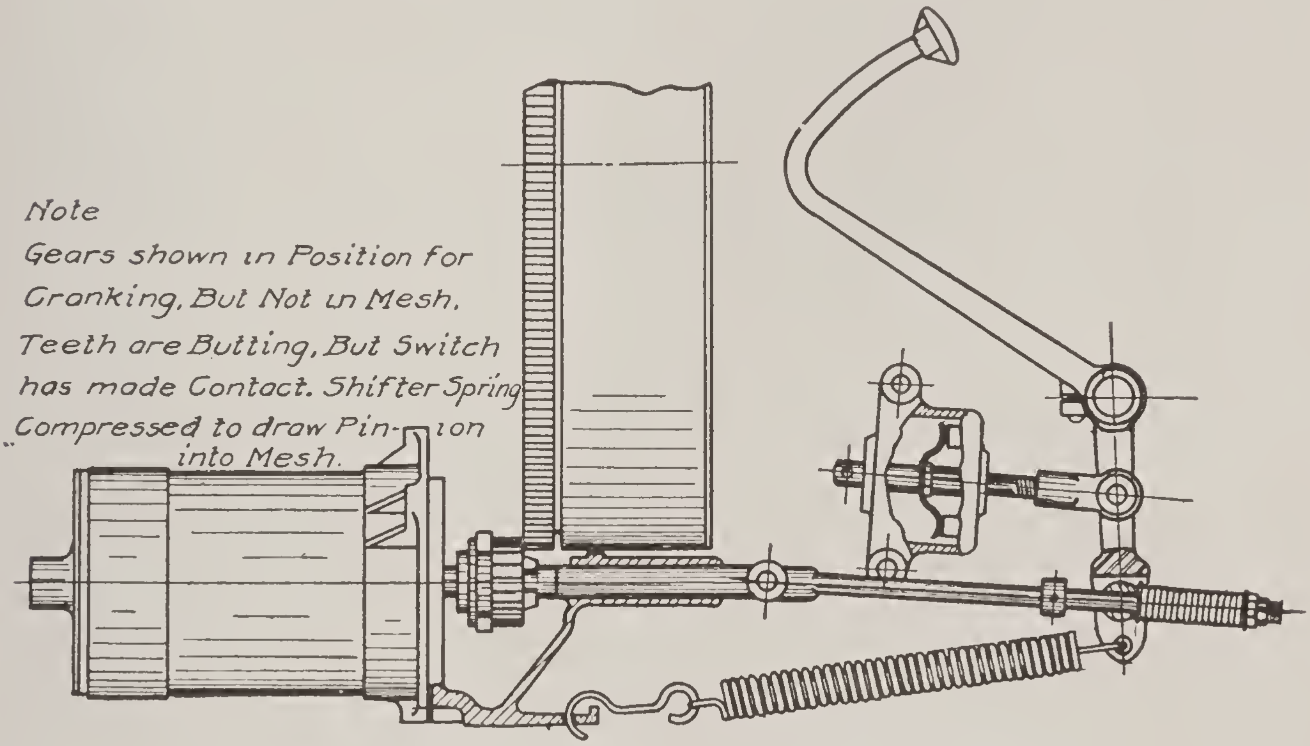


Fig. 227. Bijur Starting Motor as Installed on the Hupp

Wiring Diagrams. *Winton.* This, as shown in Fig. 228, is a single-wire system. The generator is located alongside the transmission case and is belt-driven, provision for belt adjustment being made by swinging generator to tighten belt. The numbers on the wires indicate the sizes of wire used for connecting the various apparatus. Ground connections are on engine and transmission case. In this installation the starting switch is mounted directly on the starting motor. A spare lamp circuit is provided on which a portable, trouble-hunting lamp may be connected. Fuses are provided on all lamp circuits.

Jeffery. Fig. 229 illustrates the six-volt two-wire system used on the Chesterfield Six Model. With the exception of the out-of-

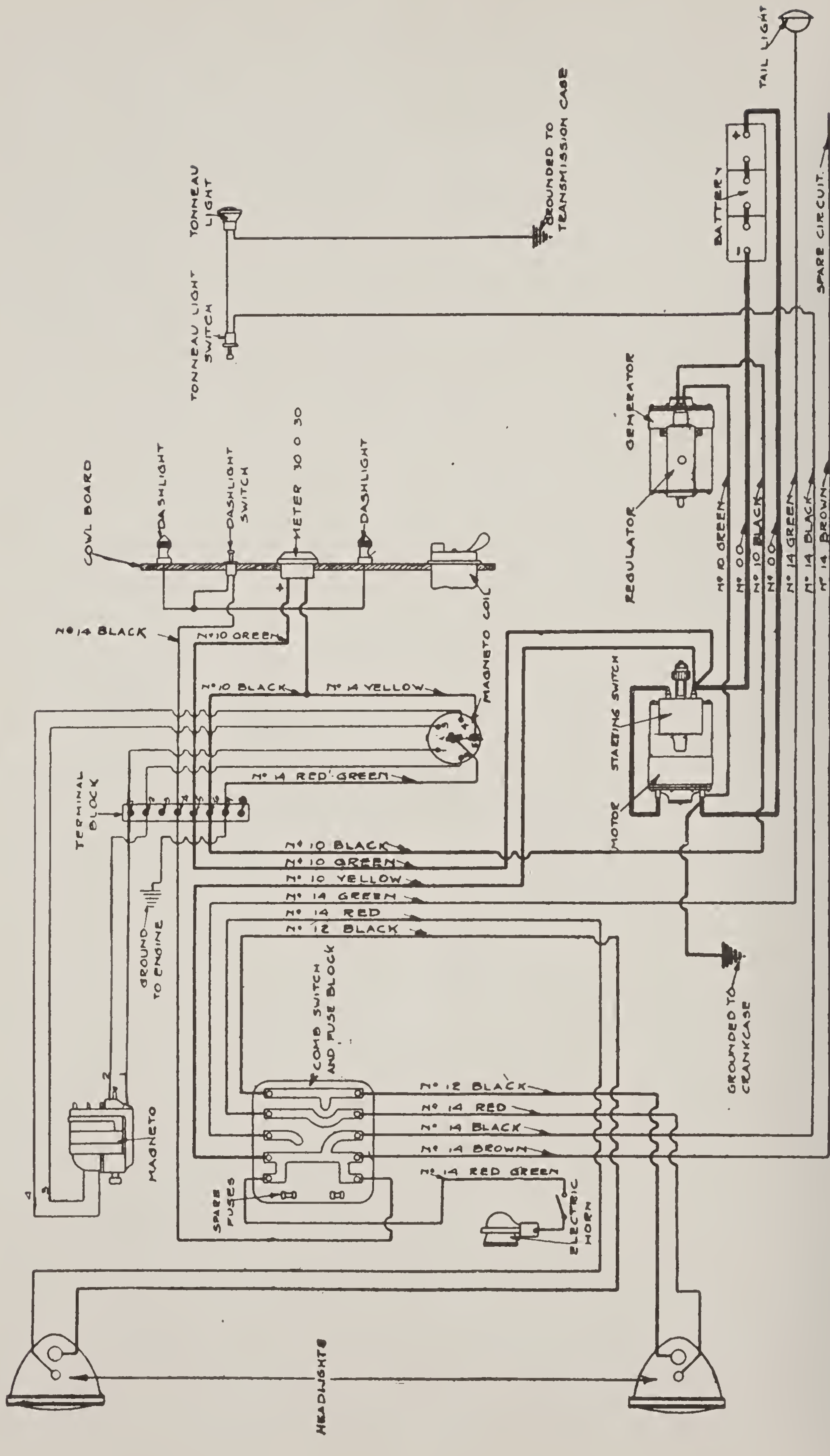


Fig. 228. Bijur System as Installed on the Winton

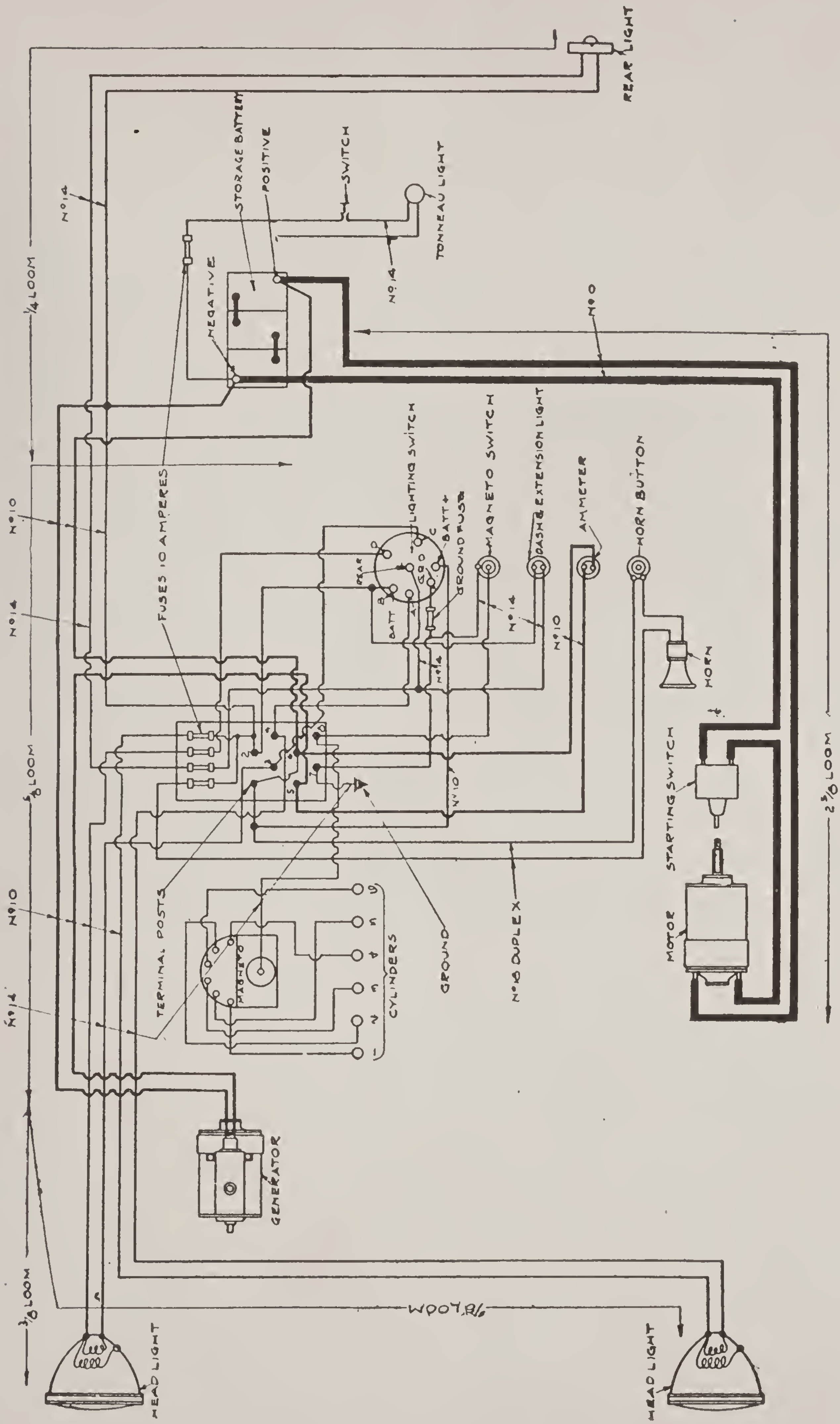


Fig. 229. Bijur System (Two-Wire) Installed on the Jeffery Chesterfield Six

focus lamps in the headlights for city running which are on the three-wire plan, one side being grounded, all apparatus is connected with two wires. In addition to lamp fuses, the ground connection is also fused. The blowing of any of these fuses does not affect the ignition circuits. The generator is mounted on the right side of the motor and is driven through a flexible coupling from the timing-gear shaft. At its rear end, the generator is connected through a jaw coupling to the water pump, this shaft also serving to drive the magneto. The starting switch is mounted on a housing covering the motor pinion, the starting motor being mounted on the left side of the engine. A five-way switch provides lamp control.

Hupp. Fig. 230 shows the 6-volt single-wire system. This diagram is simplified by the omission of the magneto, current from the battery being supplied to a single coil and distributor system for this purpose. The generator is bolted to an extension on the right side forward of the engine and is driven by silent chain from the crankshaft. The generator is of the third-brush regulation type. The field windings are protected by a 12-ampere fuse. There is a four-way switch for lighting circuits.

Apperson. The 6-volt two-wire system is shown in Fig. 231. The generator is of the third-brush regulation type. A "charge indicator" is fitted instead of an ammeter, having three readings—*charge, floating,* and *discharge. Floating* is the neutral position and the indicator should show this when the engine is stopped and no lights are on, and may show either *charge* or *floating* at car speeds in excess of 12 miles per hour with lights on, according to the condition of the battery. Generator fields are protected by a 12-ampere fuse.

Scripps-Booth. In this connection is used the 12-volt single-wire system employing a single unit or dynamotor for charging and starting. The dynamotor is driven by silent chain from the crankshaft. At speeds above 10 miles per hour, it acts as a generator to charge the battery; at speeds below this point, it automatically acts as a motor to drive the engine. Control is by three-way switch, having *on, off,* and *idle* positions.* In the *on* position, the dynamotor is connected to the battery, the generator

* Earlier models like Fig. 232 used a two-way switch.

field circuit is closed, and the ignition circuit is closed. This is the normal operating position. In the *off* position, all circuits are opened and the car cannot be run. Shifting the switch to the

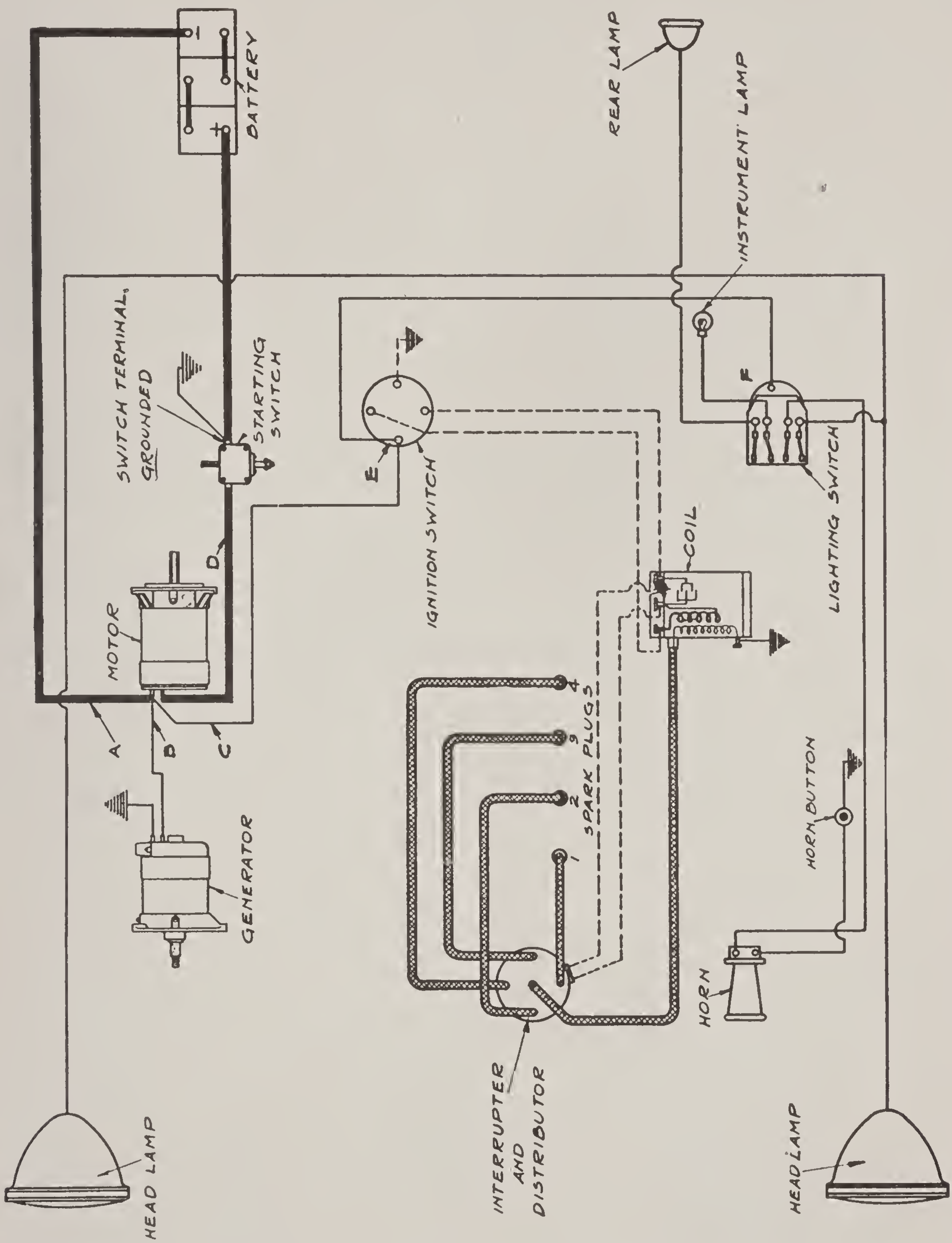


Fig. 230. Wiring Diagram for the Bijur System on the Hupmobile

idle position closes the ignition circuit so that the engine can be operated, but the dynamotor is disconnected from the battery and its field circuit is opened so that it generates no current.

Fig. 232 shows the wiring diagram as used on the earlier models of the Scripps-Booth, while Fig. 233 is the diagram of later models

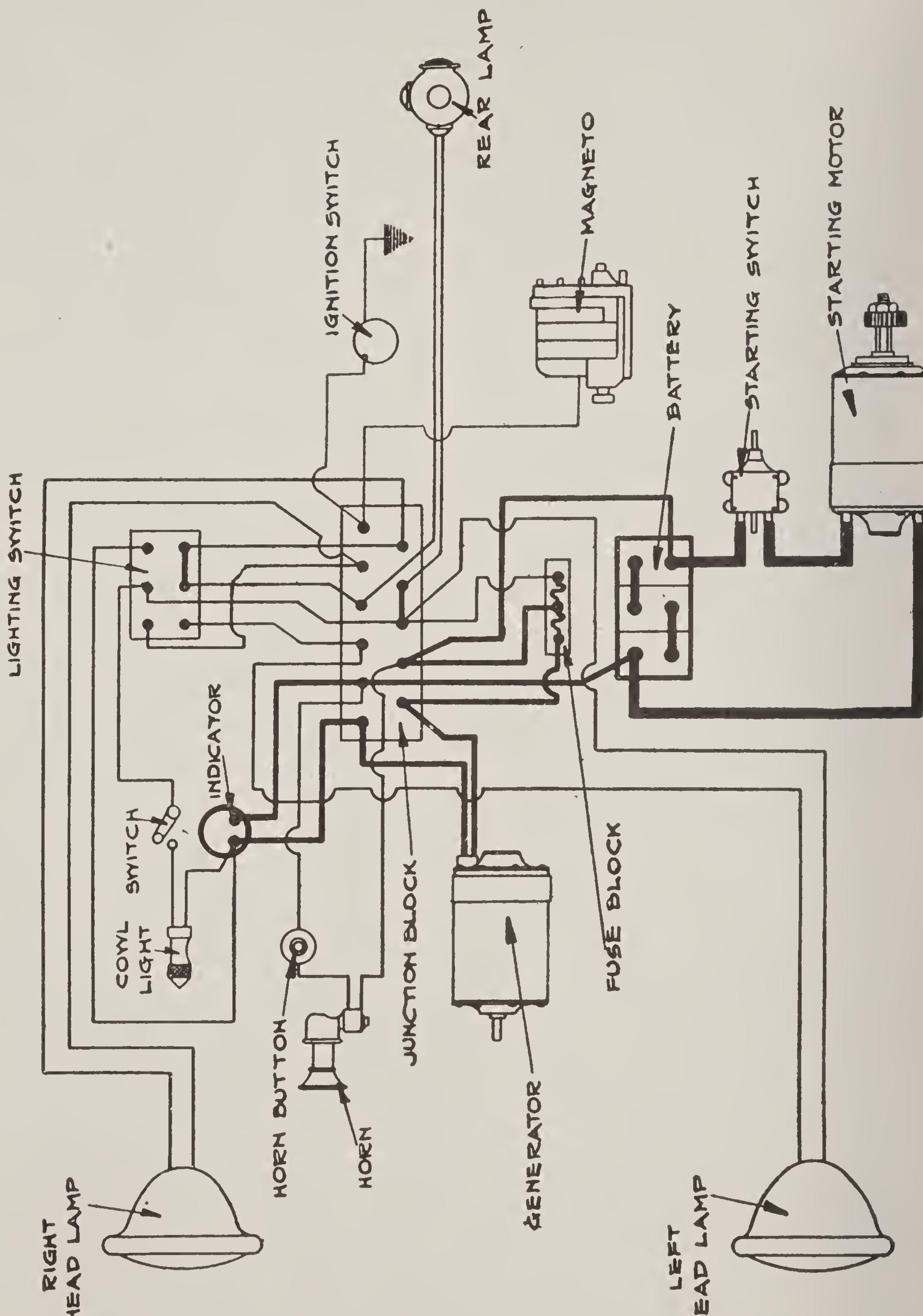


Fig. 231. Wiring Diagram for the Bijur System on the Apperson Car

of the same make. A current indicator shows the operation of the system and a four-way lighting switch is employed. The gen-

erator produces current at 12 volts and charges the storage battery cells in series. Fourteen-volt tungsten lamps are used.

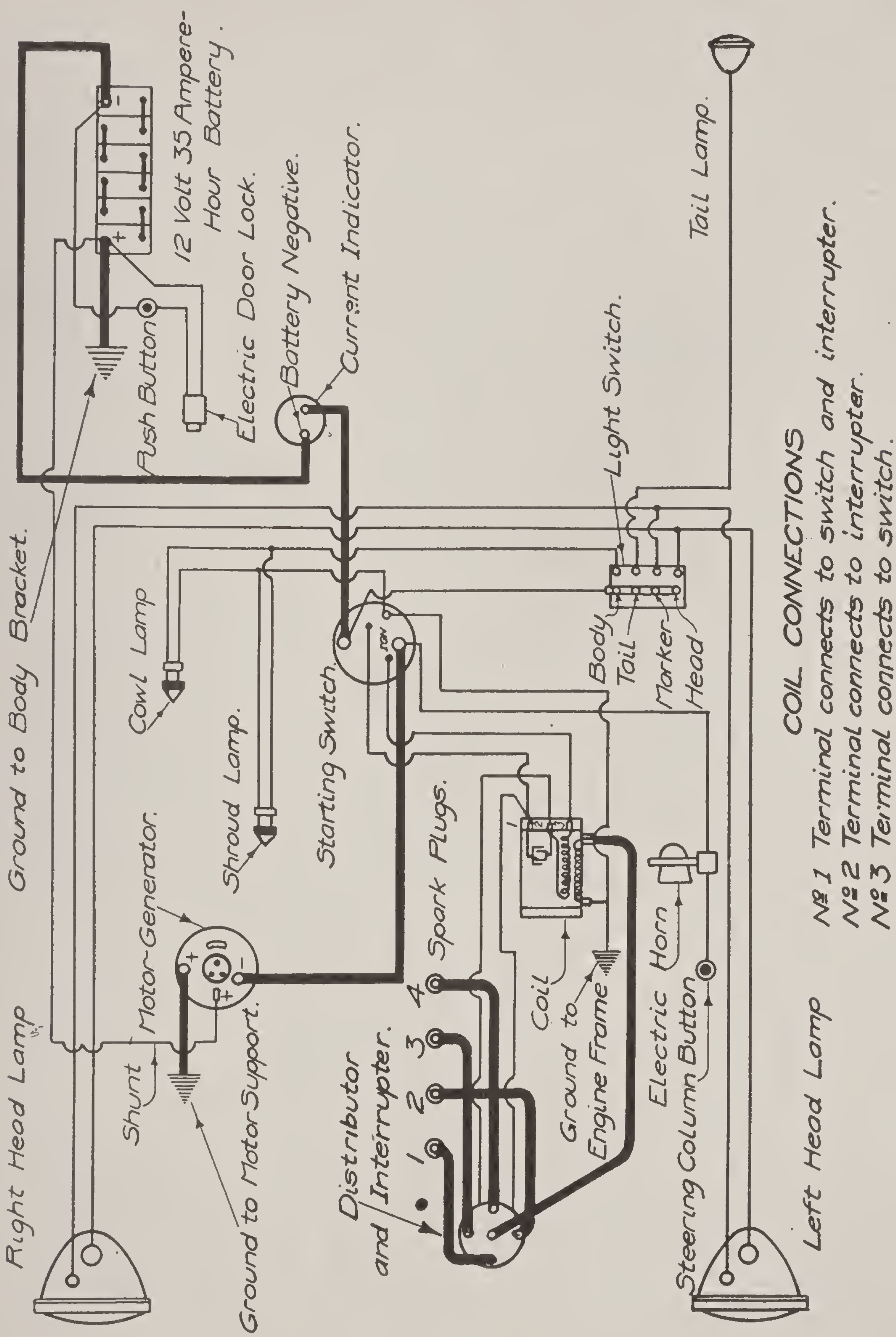


Fig. 232. Bijur System as Installed on Earlier Models of Scripps-Booth Cars

Instructions. *Winton.* No *charge* reading will be indicated on the ammeter when the engine is running (on high gear or direct

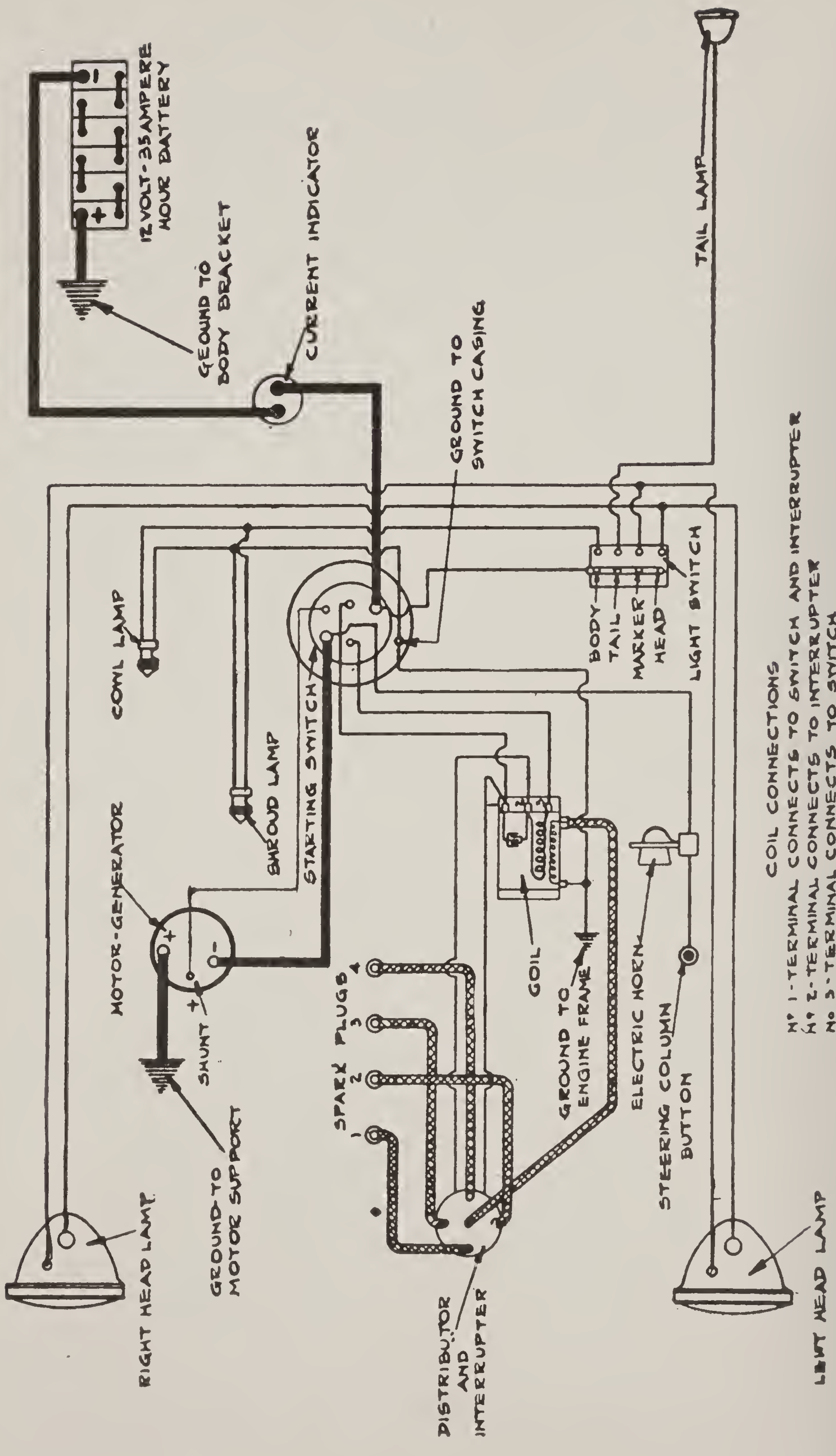


Fig. 233. Bijur System as Installed on Later Models of Scripps-Booth Cars

drive) at a car speed of less than 10 miles per hour. Failure to indicate a charge at speeds higher than this is a sign that the generator belt is too loose or that the generator itself is inoperative. To determine this, remove No. 10 black wire, Fig. 232, connected to No. 6 post on the terminal block, which goes into the aluminum box above it. Connect a voltmeter between this wire and the chassis and run the engine at a speed corresponding to a travel of 15 miles per hour on high gear. The voltmeter should indicate 7.3 to 7.4 volts. Instructions regarding brushes, commutator, and tests of armature- and field-winding circuits with the aid of testing lamp as given in connection with the Auto-Lite system apply to determine the nature of the fault in the generator. A special disconnecting plug is incorporated in the regulator box on top of the generator. This plug has two flat parallel faces and should never rest in its receptacle so that these flat faces stand in a vertical position, but should be pushed in and turned in either direction past its central position until it locks. When making tests for generator faults see that this plug is in the proper position to close the generator circuit.

To remove the regulator box from the generator, the disconnecting plug should be pushed in and turned to its central position when the plug may be withdrawn from its socket. After removing the plug, the knurled screw on top of the regulator box should be loosened and the box lifted by grasping it and the plug receptacle at the same time. Do not hammer the receptacle in order to release the box. If the disconnecting plug is round and knurled on the portion extending from the receptacle, the plug may be withdrawn when the V-groove extending horizontally on the plug matches with the slot at the top of the receptacle. The plug should never be left in this position, but should be turned in either direction until it springs forward and locks. Every five hundred miles, this disconnecting plug should be pushed inwardly to unlock it, and turned past its vertical position until it springs forward and locks. In carrying out any repairs or tests involving the disconnection of any of the wires which might cause a short circuit by coming in contact with metal parts of the car, the cable connected to the positive terminal of the battery should be disconnected and its bare end taped. This naturally applies to all grounded electrical systems and not merely to the car under consideration.

Jeffery (*Chesterfield Six*). Instructions for failure of generator, starting motor, lamp circuits, etc., are the same as those given in connection with other installations, except that in making tests the fact that two-wire circuits are employed must be borne in mind and connections made accordingly. The headlights supplied are special double-filament lamps, one of the filaments being out of focus to provide a non-glaring light for city driving. Where emergency replacements are made with standard single-filament lamps (double-contact type), the lamp controller should be turned to the *in focus bright* position when the head lamps are to be used. It is not possible to dim the lights under these conditions. In making a head-lamp double-filament bulb replacement, the lamp controller should be turned to the *out of focus dim* position. The new bulb should then be inserted in its socket. The out-of-focus filament in each headlight should then burn dimly. If they do not, the last bulb inserted in its socket should be removed, reversed, and replaced. When bulbs are correctly inserted, the two out-of-focus filaments will burn dimly when the lamp controller is turned to the *out of focus dim* position. Instructions for the use of the disconnecting plug are the same as for the Winton.

To determine whether generator is inoperative remove wire leading from the ammeter to No. 5 post of the junction and fuse block, Fig. 229, then connect voltmeter to terminals 2 and 5 and run engine as previously directed. A fuse is in the ground circuit between the magneto tap and the lamp controller and this fuse will blow if an accidental ground is made on either side of the system. The blowing of this fuse when the lamp controller is in the *off* position, shows that the accidental ground causing it is on the positive side of the system. Should the ground fuse blow when the lamp controller is in the *all bright* or *out of focus bright* positions, it shows that the accidental ground is on the negative side of the system. In testing the wiring to locate grounds, the headlight bulbs should be removed and the ground wire leading to connecting post No. 7 of the fuse and terminal block should be disconnected, and the magneto switch should be placed in the running position. With the ground fuse blown, the following lighting conditions obtain. Controller at *in focus bright* position, lamps will burn normally. At *out of focus bright* position lamps will not light; at *all bright* position

only the in-focus filaments will light. At the *out of focus dim* position all the lamps will light.

Hupp. General instructions covering failure of generator, starter, or lamp circuits apply as already given. Many other important factors might be mentioned such as open circuit, loose connections, blown generator fuse, corroded battery terminal, and brushes not seated properly. If the starting motor is damaged so that its removal is necessary, it should be removed by disconnecting one of the battery terminals and the two small wires *B* and *C* as shown on the diagram, Fig. 230. Next remove heavy cables *A* and *D* from the starting motor. The holding nuts on the motor can then be loosened to permit its removal. In replacing a starting motor, the pinion riding on the square shaft of the motor should be tested to see that it has a free sliding fit on the shaft. Do not use a file but see that all surfaces are perfectly clean and well oiled. The pinion must be guided over the shaft before the motor is pushed into place. Connect the new motor in accordance with the wiring diagram. Do not make storage-battery connections until all other connections have been made and while repairs are being carried out battery terminals should be protected.

In case an inoperative starting motor is removed and a new one is not immediately available for installation, the car may be run with the hand-starting crank by proceeding as follows: Terminals on the end of cable *A* and the wires *B* and *C* must be connected together by binding tightly with bare copper wire and then thoroughly taping so as to form a good electrical joint that is well insulated. Secure the cables and wires to adjacent parts of the car with the aid of cord or insulating tape (not with wire) so that they cannot be chafed or otherwise injured by moving about while the car is running. The heavy cable *D* must be similarly taped and secured. The lighting system is then independent of the starting system. By making a study of the wiring diagram and carefully noting the different circuits, the starting circuit may be isolated from the lighting circuits on any car having a two-unit system. Before replacing a blown fuse always examine for grounds, short-circuits, or defective bulbs. Never replace a blown fuse with anything but another of the same capacity. If it is necessary to use the car before the trouble can be located, the grounded circuit can be left open by omitting its fuse. When all lights fail this is due to an

open circuit between the battery and the fuse block. Examine the battery connections carefully and also connections of the cable A and wire C when they are connected to the starting motor; also examine the connections E at the ignition switch, F at the lighting switch, and the fuse block. If all of these connections are clean and tight, making good electrical contact, there is a broken wire between these points and the various circuits should be tried with the testing lamp.

Before making the usual tests for an inoperative generator see that the fuse protecting the field windings is intact. If this fuse has not blown and all connections are tight and properly made, remove wire from B which connects the generator to one terminal of the starting motor, and connect an ammeter in this circuit. Run the engine at a good speed, equivalent to 15 miles per hour or more. If the ammeter shows no current, while the commutator is bright, brushes bearing on it properly, and the battery connections are all right, test the armature and field windings with a lamp outfit to locate short-circuited windings. Do not remove the generator unless another is available for immediate installation. If it is necessary to run the car with the generator inoperative, the field fuse should be removed as a precaution against damage. To take the generator off, remove the circular cover plate from the front end of the chain case and take out the three bolts holding the generator to the rear side of the chain case. The driving chain should be supported through the opening at the front to prevent it from falling to the bottom of the chain case. It is not necessary to remove a pin connecting the links together. The chain may be tightened by loosening the three bolts mentioned and swinging the generator outward until the slack is taken up and then retightening the bolts.

Apperson. The generator on the Apperson system has a fuse protecting the field circuit, Fig. 231. Open connections between the generator and the battery will blow this fuse. It is located on the end of the generator adjacent to the terminals and is protected by an aluminum housing. To examine, remove the latter by taking out its two holding screws. The fuse is of the standard glass-tube type and may be lifted out of its clips with the thumb and finger. Do not attempt to pry a fuse out of its clips with a screwdriver

or other tool. Before replacing a blown fuse examine all connections and wiring to see that they are in good condition. The engine must never be run with the battery disconnected, as this will blow the generator-field fuse. These instructions apply to all generators equipped with field fuses, although the placing of the latter will naturally differ in other systems. Instructions for testing circuits are the same as those for other two-wire systems. There are no grounds except in the ignition system. Tests for inoperative generator or starting motor and instructions for the removal of either of these units are the same as already given.

Scripps-Booth. With the higher voltage battery supplied (12-volt) in the single-unit system employed on this car, the cells are of considerably smaller capacity (35-ampere-hour as compared with 80-ampere-hour on the Apperson and 120-ampere-hour on the Winton), so that if the car has been left standing for long periods with the lamps on, or is only run for short periods during the daytime, thus giving the battery no opportunity to become fully charged, it will not have sufficient capacity to start the engine. As the motor-generator (dynamotor) automatically reverses its functions in accordance with the speed at which it is being driven by the engine, the latter should not be run with the switch in the *on* position at speeds corresponding to a travel of less than 10 miles per hour. Under such conditions, as when the car is left standing with the motor idling slowly, or when driving at a very slow pace as in congested traffic, the switch should be placed at the *idle* position. Should the engine stall when the switch is at the *idle* position, it should be shifted immediately to the *on* position. For failure of the current indicator to work see instructions on this point on page 353. The indicator should never show *discharge* when the car is running above 12 miles per hour.

If necessity requires the operation of the car with the battery disconnected, disconnect the wires from the generator at the machine, as otherwise it is liable to injury. On the earlier Scripps-Booth models, Fig. 232, the engine should not be used as a brake in running down hill except in emergencies, but on later models, Fig. 233, this may be done without injury to the dynamotor by throwing the switch to the *off* position. By referring to the wiring diagram it will be noted that the shroud-lamp and cowl-lamp bulbs

are of the double-contact type; all others are of the single-contact type. All must be 14-volt lamps, 15 c.p. and 4 c.p. in the headlights and 2 c.p. for the others.

Packard. Fig. 234 is the wiring diagram of the Packard twelve-cylinder motor, showing all connections for the ignition, starting, and lighting. Beginning at the left, are the double headlights and their connections, just back of them, the twelve-cylinder distributor and its connections to the twelve spark plugs, in groups of six. This distributor is illustrated in the preceding ignition section. It is practically two six-cylinder distributor units, each of which has its own induction coil, though both naturally must run synchronously, i.e., they are timed together, as the ignition alternates from one group of cylinders to the other. The secondary cables are represented by double lines which are shown part solid and part open, to distinguish them from other wires. To the right of the two coils, in the lower central part of the diagram, is the junction box, incorporating all the lighting-circuit fuses. Further to the right of this, the "switchboard" is a unit mounted at the head of the steering column of the car and which brings to one convenient point within easy reach, all the lighting as well as the ignition switches.

To indicate the heavy cables of the starting circuit, a double line is used with cross lines at short intervals. Two-wire connections are used throughout the entire system, barring the ignition. On the motor the high- and low-tension wiring is readily distinguishable by the difference in size, the low-tension wires having the thinner insulation. The low-tension current is carried in a complete two-wire circuit not grounded at any point. The high-tension current is grounded from the spark-plug body, through the motor to the coil bracket. The starting circuit may readily be traced by its heavy connections, and it will be noted that it is the shortest and most direct circuit in the system. Referring to the junction box, the strap shown connecting posts *A* and *B* is used in this way in all states the laws of which allow direct control of the tail light from the driver's seat. With this arrangement, the dash and tail lamps are in parallel and both are protected by the tail-lamp circuit fuse. For states requiring an independent tail-lamp circuit, such as Illinois, this strap is connected across posts *B* and *C;* with this arrangement, the dome-light fuse protects the tail light, while the

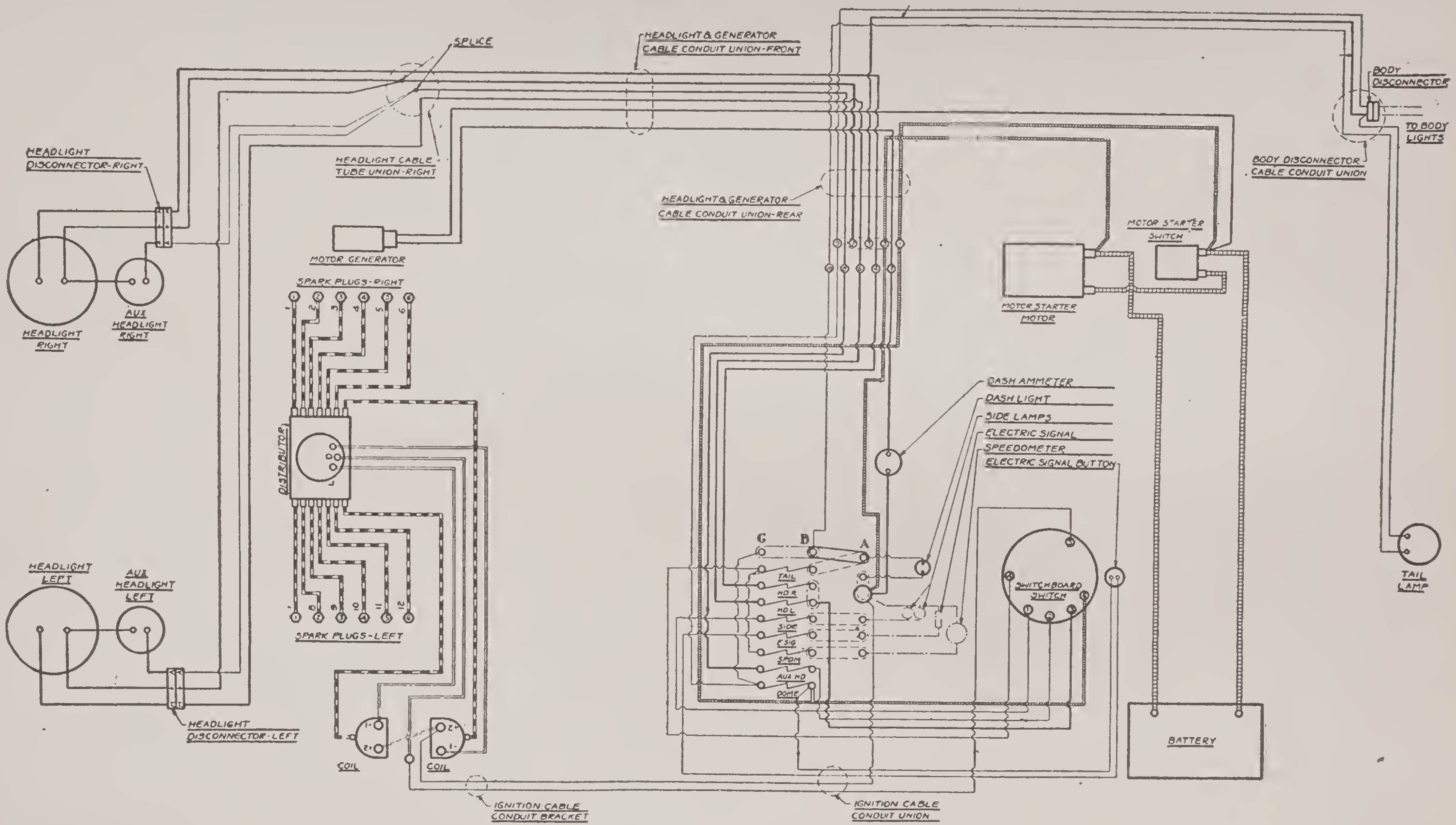


Fig. 234. Wiring Diagram of Bijur System for Packard "Twelves"

tail-light fuse protects the dash light. All wires are run in conduits, the various circuits enclosed in each conduit being indicated at different points on the diagram. High-tension wires from distributors to spark plugs are carried in tubes supported on the cylinder blocks.

BOSCH-RUSHMORE SYSTEM

Twelve-Volt; Two-Unit; Single-Wire

Generator. The bipolar shunt-wound type of generator is made in two sizes, one for driving from pump shaft, and the other for silent-chain or belt drive.

Regulation. *Ballast Coil Employed.* The regulation is the inherent type, using a bucking-coil winding in conjunction with a so-called "ballast coil" which automatically cuts the bucking coil in or out of the circuit, according to the resistance of the ballast coil. Mention has been made in Elementary Electrical Principles, Part I, that the resistance of certain metals increases greatly with an increase in their temperature. This is particularly the case with iron, and advantage has been taken of this fact in the Bosch-Rushmore generator. The ballast coil consists of a few turns of fine iron wire on a fluted porcelain rod. The bucking coil, which is simply a *reversed* field winding, has a polarity opposite to that of the winding employed to excite the field magnets. Consequently, when a current passes through it, the effect is to oppose the excitation of the field magnets. The bucking coil is connected as a shunt across the iron ballast coil, Fig. 148. The resistance of the bucking coil is considerably greater than that of the ballast coil when the iron wire is cold or only warm, so that at low engine speeds practically all the current generated passes through the shunt winding of the dynamo. However, the resistance of the wire increases at a constant rate with the current up to 10 amperes, after which it increases very suddenly owing to the heating effect of the current in the iron. Any current in excess of 10 amperes accordingly must pass through the bucking coil, which consequently tends to limit the output of the generator to that amount of current.

Starting Motor. *Method of Operation.* This is the series-wound bipolar type, as illustrated in section, Fig. 155, which shows the field windings as cut in half. As the illustration is to scale, the large size of the conductors in a series-wound field will be noted,

this being necessary owing to the heavy current required to operate a starting motor. The starter pinion is mounted directly on the armature shaft without any intermediate gearing and the engagement of this pinion with the flywheel gear is automatic, as will be made clear by referring to Fig. 155, and to Fig. 165, showing the mounting of the Bosch starter on an automobile motor.

Refer back for a moment to the description of magnetic fields under Electrical Principles, Part I. See also the description of the action of a solenoid. It will be noted that every magnet has a magnetic circuit and that the lines of force comprising it are most numerous in close proximity to the poles of the magnet. In other words, the magnetic attraction is most intense at those points. The magnetic poles of the field of the Bosch starter are the metal projections each of which is held in place by two machine screws, top and bottom, as will be seen in the sectional view. It will also be plain that the armature of the starting motor is not directly in the magnetic field of these poles, and that it is held in this off-center position by the spring pressing against its shaft as seen at the left. The moment the switch is closed, however, and the field magnets are excited, the whole motor acts as a solenoid and forcibly pulls its armature into a central position against the spring, at the same time as it begins to revolve. This gives ideal conditions for meshing the starter pinion with the flywheel gear, as it is pulled against the latter and at the same time revolved, so that the moment its teeth correspond with spaces in the flywheel gear, it slips into engagement and begins to turn the engine over. As soon as the current is cut off by opening the switch, the spring returns the armature to its normal inoperative position and disengages the gears.

Starting Switch. There are two contacts on the starting switch, the first sending only a small amount of current through the starting motor, this being just sufficient to pull the armature into center and engage the gears, when a further movement of the switch sends the full current from the battery through the starting motor. This progressive movement of the switch and the two circuits between the battery and starting motor are shown in Figs. 235 and 236. It will be noted that the first movement of the switch throws the field of the starter in shunt with its armature, thus causing it to revolve slowly, while the further movement of the switch places

the field in series. Fig. 237 shows the actual wiring diagram of the starting-motor circuit. In actual operation, the movement of the

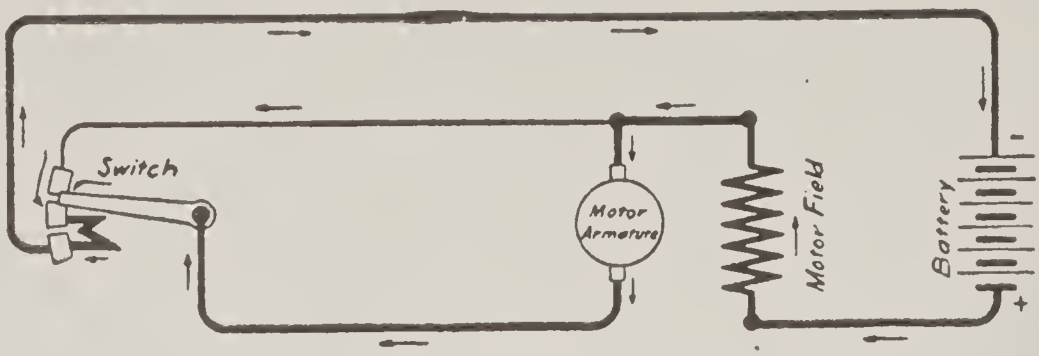


Fig. 235. Wiring Diagram for First Part of Downward Movement of Bosch Switch Pedal

switch is practically instantaneous. No damage will result in case the switch is held down after the engine starts, as the moment the latter begins to fire, the load on the starting motor is greatly reduced and the current consumption decreases to a point where the field coils no longer have sufficient pull to overcome the spring on the armature. The pinion on the shaft of the latter is automatically disengaged from the flywheel gear and the motor will only idle slowly, owing to the armature being off center.

Instruments and Protective Devices. A standard double-reading ammeter is supplied. The normal charging rate is approximately 20 amperes with the car running 20 to 25 miles an hour or over.

In addition to the usual battery cut-out which is an essential feature of most electric lighting and starting systems and will be found on most cars so equipped, whether it is specifically mentioned in the description of the various systems or not, a ballast coil is inserted in the charging circuit. This is similar to the ballast coil used in the regulation of the generator. This ballast coil is controlled

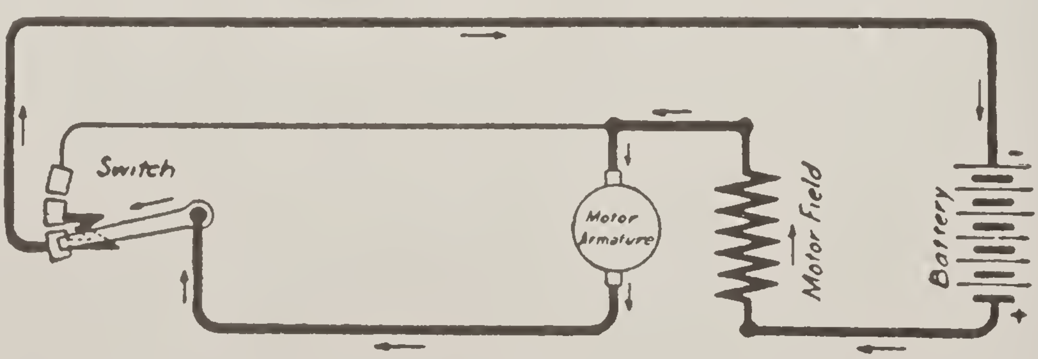


Fig. 236. Wiring Diagram for Circuit When Switch Pedal Has Completed Downward Movement

by the left-hand button of the switch (installation on Mercer cars), and its function is to prevent overcharging of the battery. By

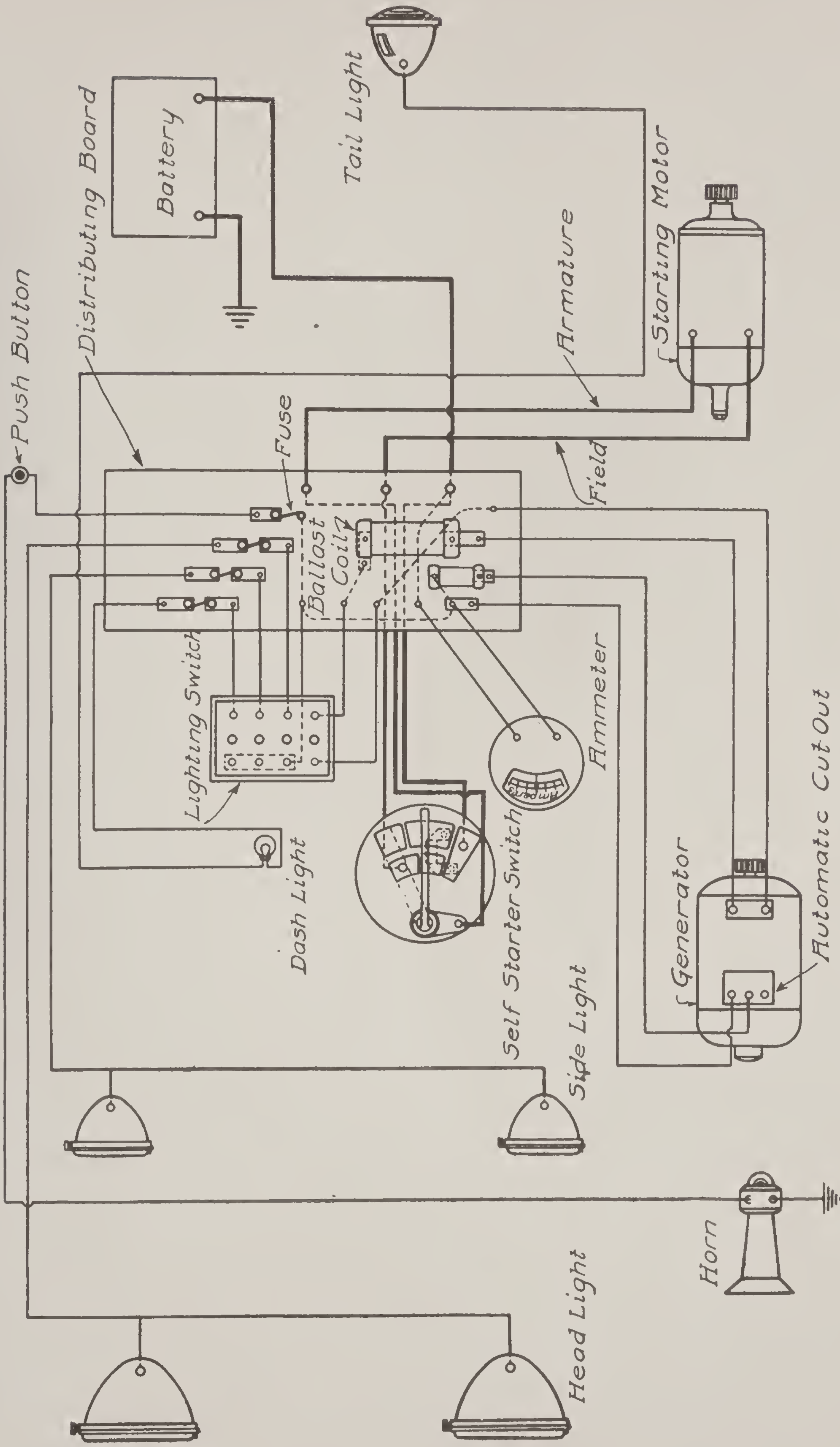


Fig. 237. Wiring Diagram for Bosch-Rushmore Starting System on a Mercer Car

putting it in the circuit the charging rate is reduced to 5 amperes. Where a great amount of day running is done, it is recommended that the ballast coil be left in circuit. All circuits, except starting motor, but including field coil of generator, are fused.

Wiring Diagram. The various circuits of the single-wire system, as employed in the Mercer installation, are shown in Fig. 237. The automatic cut-out for the battery circuit is mounted on the generator. Ground connections are not indicated in every instance, as in the case of the generator and the starter they are made within the apparatus itself, and this is also the case with the lamps, which are known as the single-contact type. The latter are employed in all single-wire systems. In this case, they must be 12-volt bulbs as six cells of battery are employed. In making lamp replacements, only bulbs of the proper type, i.e., single or double contact, depending on whether the system is one- or two-wire, and of the proper voltage must be used. This, of course, applies to all electric systems, as, where a 6-volt bulb is placed on a 12-volt system, it will be burned out immediately. A 12-volt bulb on a 6-volt circuit will burn very dimly, so that when only one headlight burns brightly the voltage of the dim burning bulb should be ascertained before looking for trouble elsewhere. If the manufacturer's label has disappeared from the bulb, it can be tested with dry cells, starting with four in series which should make a 6-volt bulb burn brightly, and increasing to eight in series for a 12-volt bulb.

Instructions. *Battery Charging.* With all lamps on, the lighting equipment consumes about 12 amperes; the side and tail lamps together take about 3 amperes, so that when the ammeter reading shows a consumption in excess of these figures for the conditions given, the usual tests should be made for short circuits or grounds. The latter will be the case also when the ammeter shows any *discharge* reading with all lamps off. Any discharge under such conditions is *leakage.* However small it may be, it should be investigated at once, as it will run the battery down. The trouble may consist of a short circuit in one of the lighting circuits or it may be due to current flowing back through the generator caused by the failure of the cut-out to work properly. In case the lamps burn dimly when the generator is at rest, it indicates that the charging rate is not sufficient to keep the battery up. This may be caused

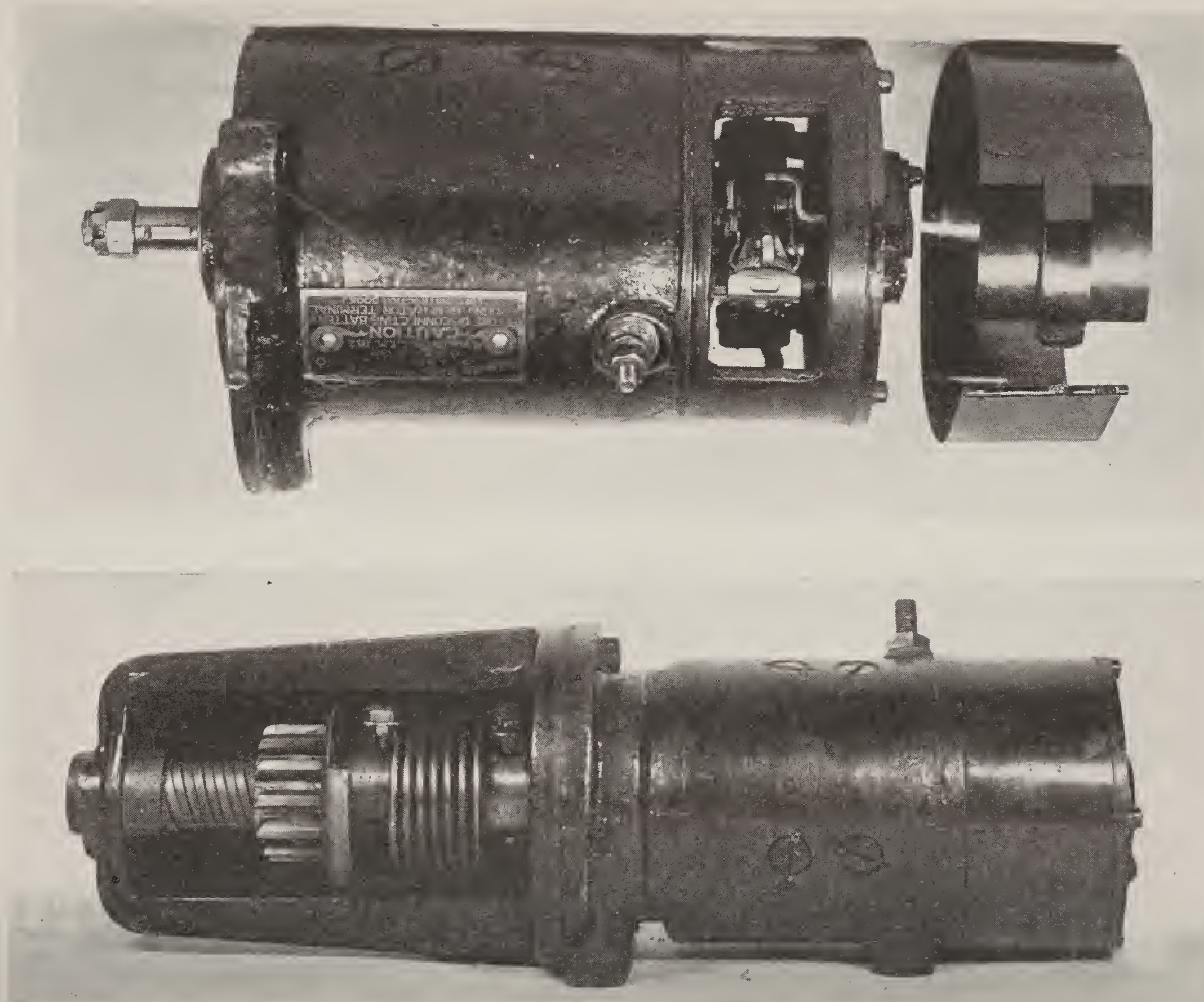
by a great deal of night running with the ballast coil in the charging circuit, as the charging rate is then only about 5 amperes. In the majority of instances, however, it will be found, probably, that the battery itself is responsible. For instructions on battery maintenance, see end of this article.

The battery furnished on the Mercer has a capacity of 120 ampere-hours. The starting motor takes approximately 200 amperes for its operation which, with the engine in good condition, should not consume more than 10 seconds for each start. To replenish the current consumed by starting twelve times in a day, or say a total of two minutes' operation of the starting motor at the 200-ampere rate, the engine would have to run only about half an hour at the average charging rate of 15 amperes. With the current consumed by the lamps, based upon their use for 5 hours per night, plus the natural deterioration losses of the battery, drop in efficiency through switches, contacts, and wiring, approximately two hours of daylight running would be required to keep the battery fully charged. Night running can be disregarded where battery charging is concerned, as the total consumption of the lamps is practically the equivalent of the average charging rate. An undue brilliancy of the lamps would indicate a battery wire off or loose and should be investigated.

Fuses. When ammeter shows no reading of charging current with the engine running, the most likely place to look for the trouble is the fuse protecting the generator field circuit. (This applies to all generators so equipped.) The field fuse of the Bosch-Rushmore generator is located on the distributing board, and it may be tested by short-circuiting the ends of the fuse cartridge with a pair of pliers, a screw driver, or other piece of metal. In case the ammeter then registers a charging current, the fuse has been blown out and should be replaced with another of the same type and capacity. As all circuits, except the starting motor, are fused, a similar test can be carried out in case of the failure of any of them. The blowing of a fuse is usually due to a short circuit, and before replacing it, the reading on the ammeter should be noted when the fuse terminals are short-circuited with the pliers, the generator being idle. A short circuit will be indicated by the needle of the ammeter moving sharply to the limit of its travel on the scale. The use of the testing

lamp for finding short circuits is given in connection with the instructions under Auto-Lite, Delco, Gray & Davis, and other systems.

Gear Meshing. Faliure of the starting motor to operate will be due to an exhausted battery in the majority of instances, but on cars that have seen considerable service, it may be caused by a settling or distortion of the frame resulting in binding of the gear teeth too tightly. This may be corrected by readjusting the mounting of the starting motor in its supporting cradle so that the gears mesh quite loosely. It should always be possible to push the gears into mesh by hand without any effort. Unusually slow operation of the starting switch may also cause failure of the starting motor to operate properly. The first contact of the switch places a small resistance in the circuit and too long a delay may overheat this resistance to such an extent as to burn it out. Over-rapid operation of the switch may also cause failure to start as the gears are not allowed to mesh. This will be indicated by their clashing and by the spinning of the starting motor. The switch should be given a comparatively slow but steady movement from first to second contact.



WAGNER GENERATOR AND STARTING MOTOR AS DESIGNED FOR SCRIPPS-BOOTH CARS
Courtesy of Wagner Electric and Manufacturing Company, St. Louis, Missouri

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART V

ELECTRIC STARTING AND LIGHTING SYSTEMS—(Continued)

PRACTICAL ANALYSIS OF TYPES—(Continued)

DELCO SYSTEM

Six-Volt; Single-Unit; Single-Wire

Dynamotor. The dynamotor is usually referred to as a motor-generator, though it is actually a generator-motor, i.e., a dynamo-motor which has been shortened to dynamotor. This term has been adopted by the Society of Automobile Engineers to designate the combination unit in question. A motor-generator as employed for transforming alternating current to direct current consists of two separate units: a motor driven by alternating current and a dynamo generating direct current, mounted on the same bed, and with their armature shafts directly coupled.

The Delco single-unit machine consists of two separate field windings and two independent armature windings, the latter being connected to separate commutators at either end of the shaft. In combination with this is an ignition timer and distributor mounted at the generator end and driven from the armature shaft through spiral gears. The generator is driven from the pump shaft of the engine through an over-running clutch which permits the armature to run free when the unit is operating as a starting motor. At the starter end, the armature shaft carries a small pinion meshing with the larger unit of a pair of sliding gears, the smaller of which is adapted to slide into engagement with the gear ring of the flywheel. This arrangement is shown clearly in Fig. 238; it provides a double gear reduction between the starting motor and the engine. In the

smaller of the two sliding gears is incorporated an over-running clutch which releases the starting motor from the engine in case the latter should be speeded up without disengaging the starting gears, thus preventing damage to the starting motor by running it at an excessive speed.

Control. The necessary switches for putting the generator in circuit to charge the battery, and to cut it out of this circuit and put the starting motor in circuit with the battery to turn the engine over, are built into the machine and take the form of lifting brushes. Their operation is as follows:

To start, the ignition button on the switch panel on the dash is first pulled out. This connects the storage battery with the ignition

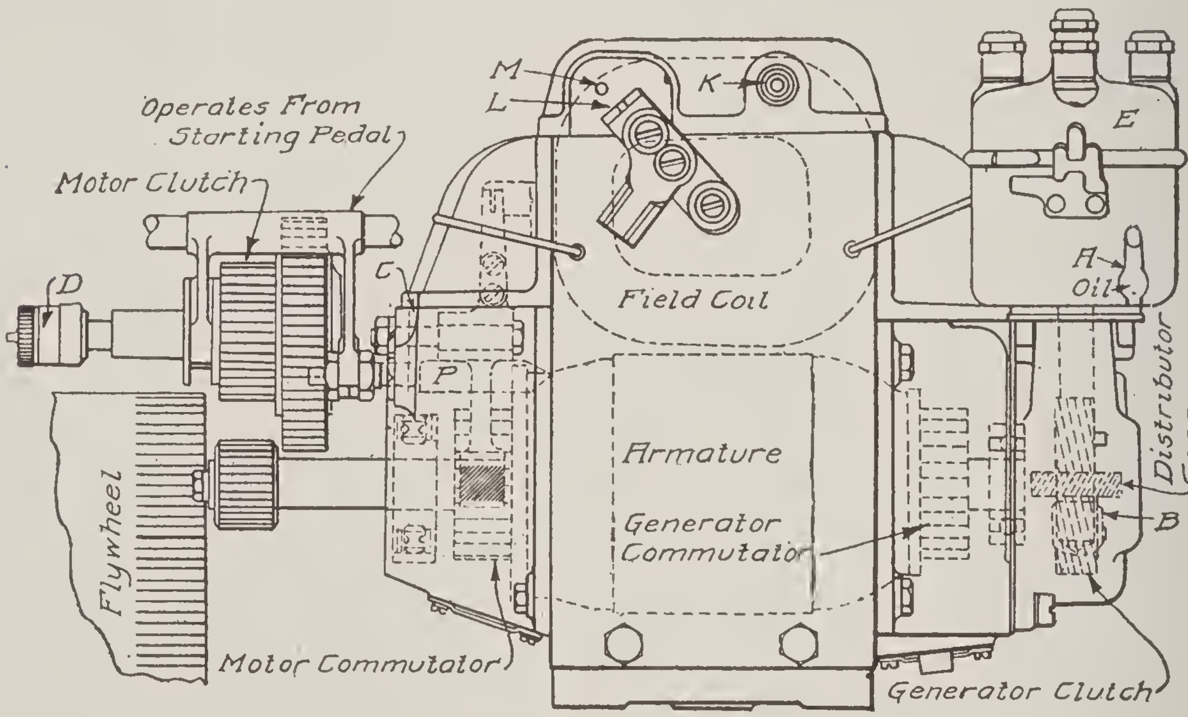


Fig. 238. Diagram of Delco Dynamotor for Single-Unit System

circuit and with the armature of the dynamotor through a resistance which permits only a current of small value to pass. This current *motorizes* the generator and causes its armature to rotate slowly, giving it just enough speed to facilitate the meshing of the starting gears. The starting pedal is then depressed and during the first part of its travel it serves to engage the gears, Fig. 238. Then it withdraws the pin *P*, Fig. 239, allowing the motor brush switch to make contact with the motor commutator. At the same time it causes the generator switch to open, thus cutting out the generator during the cranking operation. As soon as the motor brush makes contact, the full current from the battery passes through the series-

field winding of the motor element and through the corresponding armature windings, and sets the armature rotating at full speed.

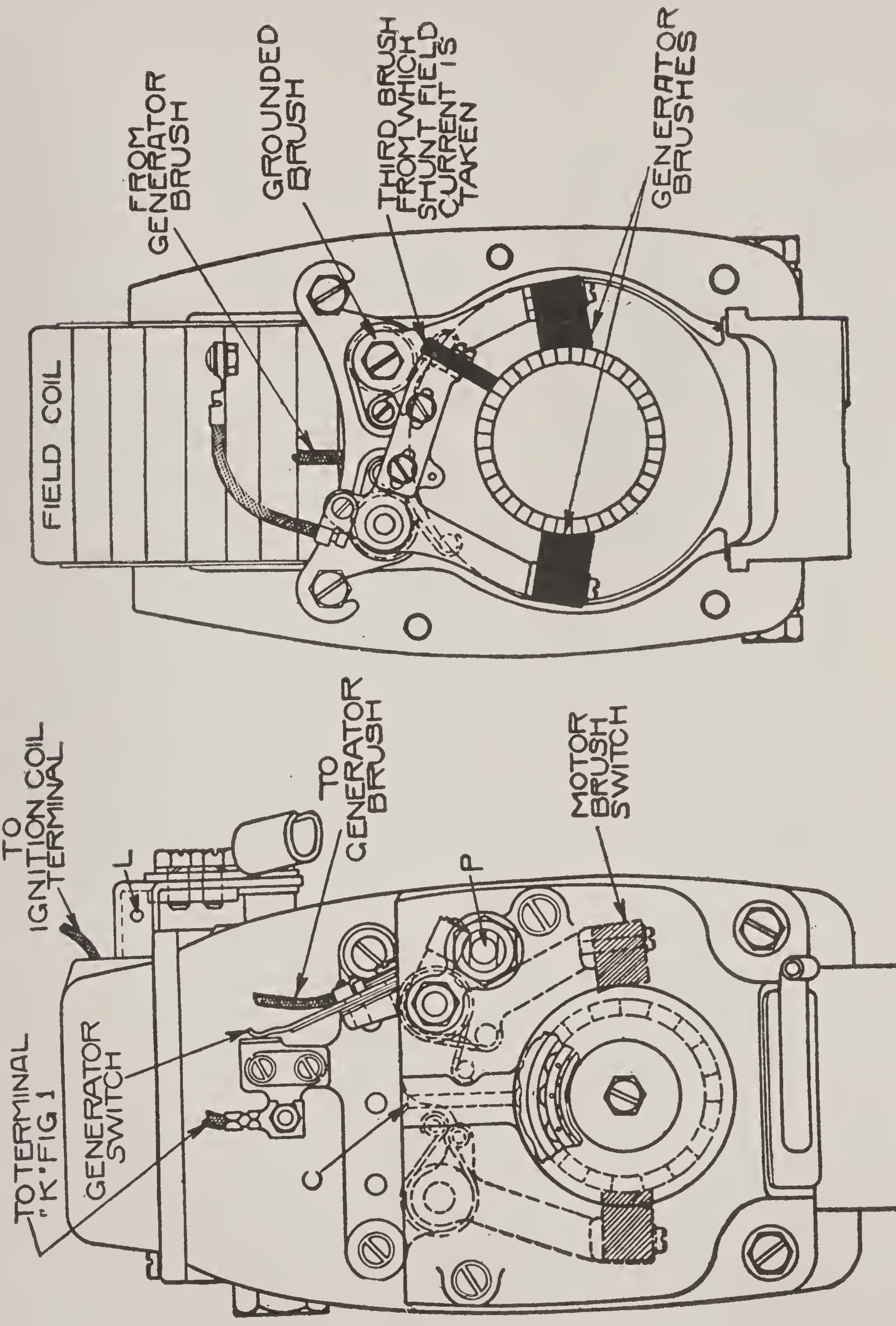


Fig. 239. Details of Brushes and Brush Switches, Delco Single-Unit System

The starter pedal is returned to the open position by a spring and as soon as it is released, the motor brush is lifted from its com-

mutator and the generator switch is closed, thus cutting out the motor windings and connecting the unit to the storage battery as a generator. Charging begins when the engine reaches a speed corresponding to 7 miles per hour.

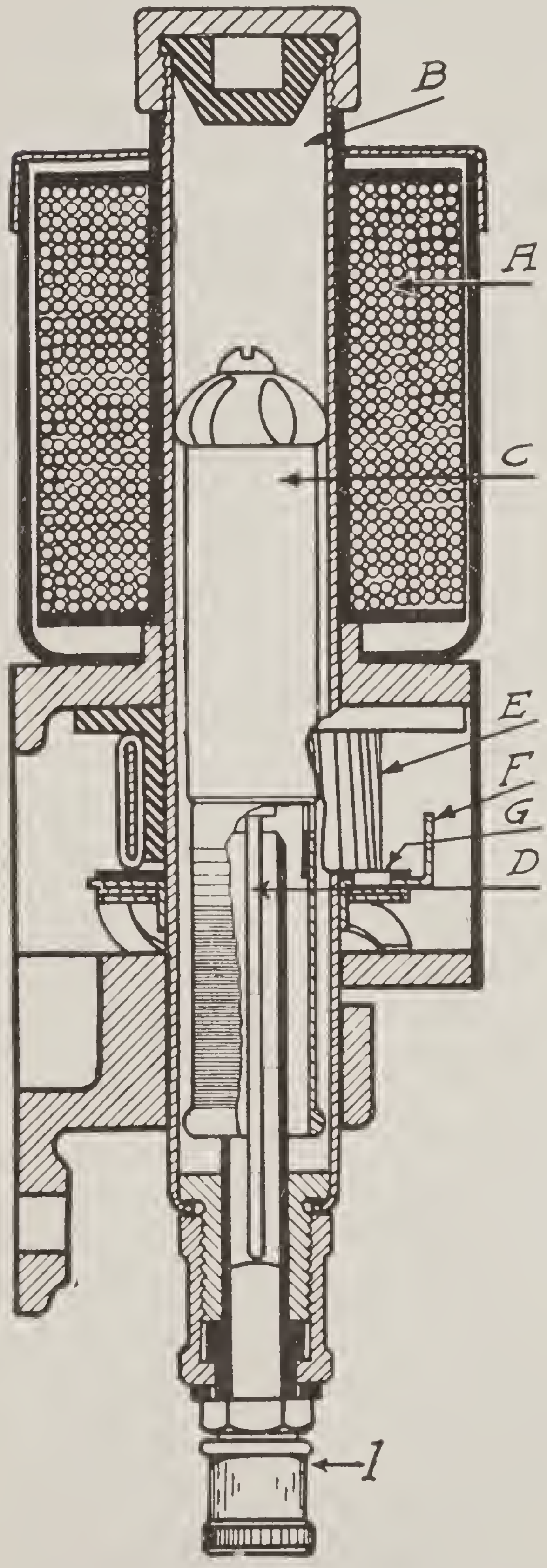


Fig. 240. Section Showing Delco Mercury-Bath Voltage Regulator

Regulation. *Constant-Voltage Control Type.* Of the four types produced the first employs a resistance variable in accordance with the speed. The regulator consists of a solenoid the core of which has a spool of resistance wire wound on its lower end, Fig. 240. This core or plunger *C* floats in a bath of mercury, and, in accordance with the depth to which it sinks in the mercury, more or less of the resistance wire is short-circuited by the mercury. The solenoid winding *A* is connected in shunt across the generator terminals so the current flowing through it and the magnetic effect exerted by it are always proportional to the voltage at the generator terminals. The resistance wire on the plunger of the solenoid is in series with the shunt-field winding of the generator. If there were no other forces than the buoyancy of the mercury and that of gravity acting upon the plunger it would remain at approximately the same height, but as the plunger is iron it is acted upon by the solenoid winding, the effect being to withdraw it from the mercury as the current through the winding of the solenoid increases, thus putting more and more of the turns of resistance wire on the spool in circuit. Hence, the greater the current flowing through the solenoid the greater will be the resistance in circuit with

the shunt-field winding of the generator. To overcome the effect of temperature variation on its operation which would cause the charging rate to be higher than intended at high temperatures, and *vice versa*, the solenoid is wound and connected in series with a resistance wire of special material having a negative temperature coefficient (i.e., whose electrical resistance decreases with an increase in temperature), so that the total resistance of the solenoid circuit remains the same regardless of temperature changes. With a few exceptions, such as the Olds 1915 Model 55, this method of voltage regulation is not employed on cars subsequent to 1914.

Bucking-Coil Type. This is the type of regulation usually referred to as *inherent* in that it is accomplished by the windings of the generator itself. The latter is compound wound but the series field has a reversed polarity, so that its effect is to oppose that of the shunt winding.

Mechanically Varied Resistance. In this type the same principle as that employed in the first type described is used, i.e., that of weakening the generator field by increasing the amount of resistance in circuit with it in accordance with the speed, except that it is varied by mechanical means instead of electrical. The regulator resistance is in the form of a rheostat, the arm of which is controlled by a centrifugal governor driven from the shaft of the ignition distributor. As the weighted element of the governor expands under the influence of the increasing speed, it moves the arm of the rheostat over the contacts each of which represents an added resistance to the circuit.

Both the bucking-coil type and the mechanically varied type of regulation are employed in Delco systems installed on 1915 and subsequent cars, different models of the same make and the same year having different systems, so that instructions for their maintenance depend upon the system employed.

Third-Brush Method. As the voltage generated varies directly with the speed, it is evident that to maintain a nearly constant voltage with a variable speed, it becomes necessary to decrease the magnetic field as the speed increases. Since the magnetic field of the generator is produced by the current in the shunt-field winding, a decrease in this current as the speed increases will regulate the output. Bearing in mind that a current always produces a mag-

netic field, whether the latter is desired or not, the theory of this method of regulation will be clear from the following reference to Fig. 241. The full voltage of the generator is obtained from the brushes *C* and *D*. When the magnetic field from the pole pieces *N* and *S* is not disturbed by any other influence, each coil is generating uniformly as it passes under the pole pieces; the voltage from one commutator bar to the next is practically uniform all around the commutator. Therefore, the voltage from brush *C* to brush *E* is about 5 volts, when the total voltage between the main brushes *C* and *D* is $6\frac{1}{2}$ volts and current at 5 volts' pressure is supplied to the shunt-field winding. This voltage is sufficient to cause approximately $1\frac{1}{4}$ amperes to flow through that winding.

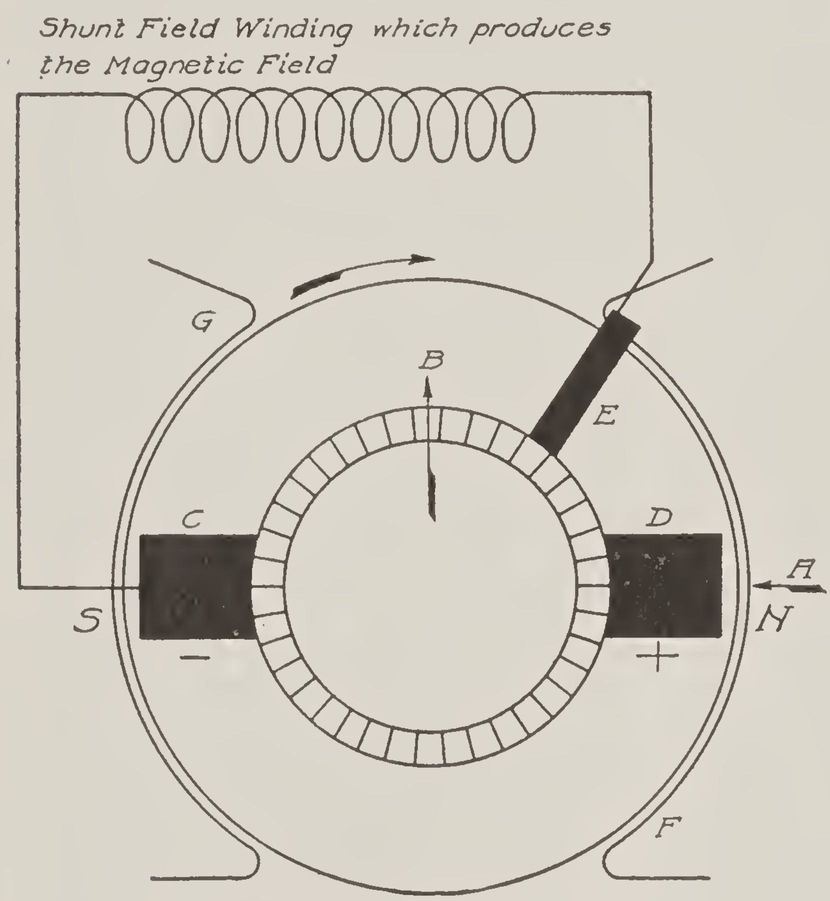


Fig. 241. Delco Third-Brush Regulator

As the speed increases, the voltage does likewise, charging the battery. This charging current flows through the armature winding causing a magnetic effect in the direction of the arrow *B* and the latter acts upon the main magnetic field, which is in the direction of *A*, with the result that the latter is twisted or distorted out of its original position, in much the same manner as two streams of water meeting are deflected from their original directions. This deflection causes the magnetic field to be strong at the pole tips *G* and *F*, and weak at the opposite tips, with the result that the coils generate a very low voltage while passing from brush *C* to brush *E* (the coils at this time are under the pole tips having a weak field) and produce the greater part of their voltage while passing from brush *E* to brush *D*. The amount of this variation depends upon the speed at which the generator is driven, thus decreasing the current supplied to the shunt field as the speed increases.

Protective Devices. *Battery Cut-Out.* In connection with Delco systems using the voltage regulator of the mercury type already described, a battery cut-out or a *cut-out relay,* as it is sometimes termed, is employed. Fig. 242 shows this cut-out together with a diagram of its windings. It consists essentially of a compound-wound electromagnet and a set of contacts designed to be closed by the movement of the pivoted armature of the magnet, and to be opened by a spring when the magnet is not excited. The compound winding consists of a voltage coil of a great many turns

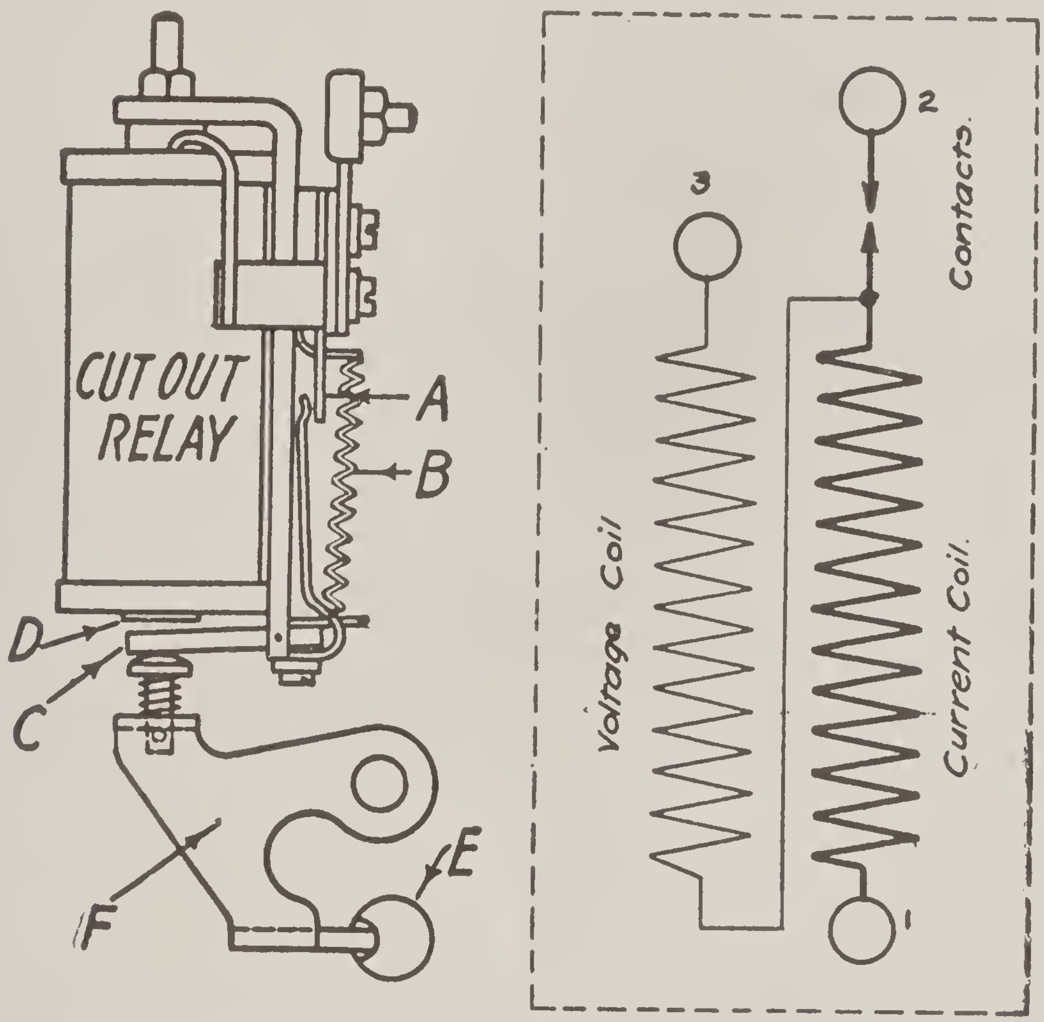


Fig. 242. Sketch and Diagram for Delco Cut-Out Relay

of fine wire, as shown at the left of the wiring diagram, and a current coil of a comparatively few turns of heavier wire. As soon as the engine begins to drive the generator the voltage of the latter "builds up" and when it reaches a value between $6\frac{1}{2}$ and $7\frac{3}{4}$ volts, the current passes through the voltage winding of the electromagnet and produces sufficient magnetism to overcome the tension of the spring *B*, attracting the armature *C* to the core *D* which closes the contacts at *A*. These contacts close the circuit between the generator and the storage battery and the whole output of the generator then flows

through the current coil, greatly increasing the magnetism in the core in the same direction thus strengthening the pull on the armature C and holding the contacts tightly closed. When the generator slows down and the voltage drops below that of the battery, current flows from the latter to the generator through the current coil in the reverse direction. But, as the voltage coil is directly in circuit with the generator, the flow of current through it continues in the same direction, so that the magnetizing effect of the battery current through the current coil opposes that produced by the voltage coil and the latter is not sufficient to hold the armature against the spring. This causes the contacts to open and prevents any further flow from the battery through the generator. The relay is designed

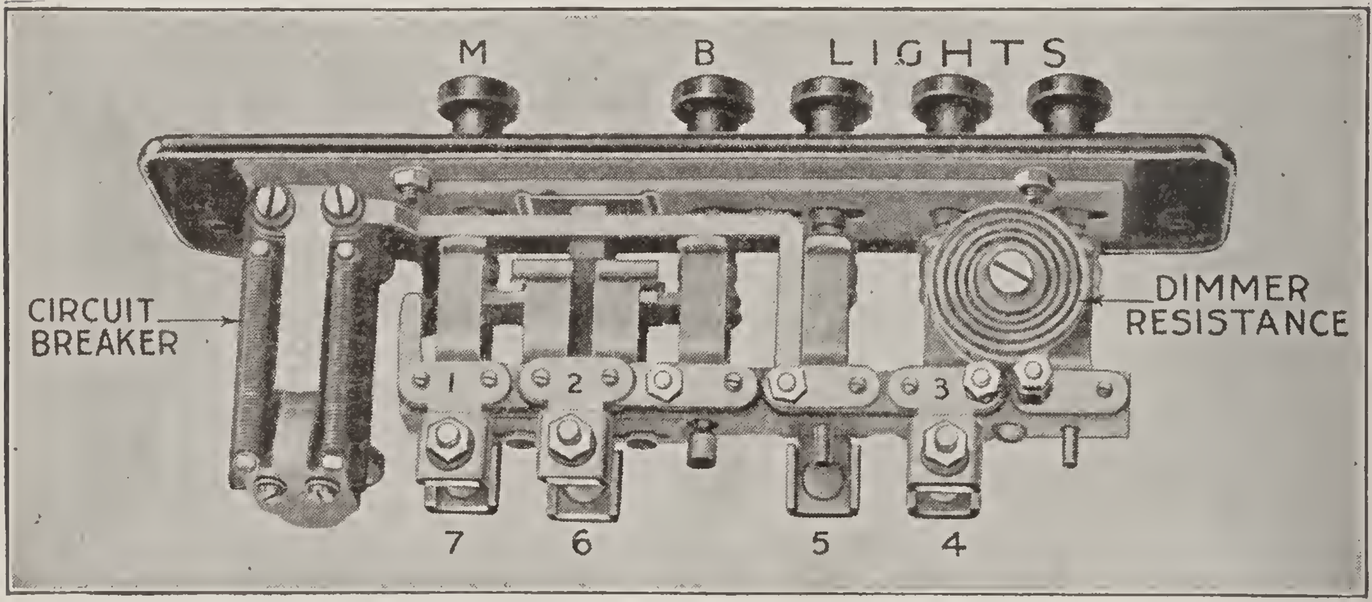


Fig. 243. Delco Combination Switch
Courtesy of Dayton Electrical Engineering Laboratories Company, Dayton, Ohio

to cut out the battery before the discharge current reaches a value of 1 ampere. As mentioned previously, but few cars subsequent to 1914 are fitted with systems using the mercury voltage regulator and only these systems are equipped with a battery cut-out.

Circuit Breaker. Delco systems fitted to cars subsequent to 1914 are protected by a circuit breaker. This takes the place of the fuse block and fuses employed in most other systems. It is mounted on the combination switch controlling the ignition, generator, and lights, as shown by Fig. 243. The button M controls the magneto ignition circuit, and the button B the dry-battery circuit for the same purpose. In addition both these buttons control the circuit between the battery and the generator for the purpose of

motorizing the latter to start. When the circuit is closed by either button M or button B, current flows from the battery to the generator, when the engine is not running and when it is running at speeds below 300 r.p.m., but the amount of current flowing at the lowest engine speeds possible is so small as to be negligible. With the engine stopped, pulling out the button M sends sufficient current through the generator armature to run it slowly as a motor so that the gears may be meshed for starting. The amount of current thus employed is limited by a resistance unit in series with the shunt field of the generator.

In principle the circuit breaker is the same as an ordinary electric bell or buzzer, but its winding and the spring controlling its armature are such that it comes into action only when a heavy current passes through it. It is included in every circuit of the electrical system, including the ignition, with the exception of the starting-motor circuit, so that all the current used for every purpose except starting passes through it. But as long as the lamps, ignition, and horn are consuming the normal amount of current, it is not affected. In case any of the wires of these circuits becomes grounded, however, a heavy current passes through the circuit breaker, thus producing a strong magnetic pull which attracts the armature and breaks the circuit. This cuts off the flow of current and the spring again closes the contacts, causing the circuit breaker to pass an intermittent current by vibrating its armature. A current of 25 amperes is required to operate the circuit breaker, but once started it will continue to vibrate on a current as low as 3 to 5 amperes.

Wiring Diagrams. The Delco system is applied to such a number of different makes of cars, frequently varying in detail not only with each succeeding year's models of the same make, but also on different models of the same make and same year of production, that space would not permit of reproducing them all here. While these wiring diagrams differ in detail, they may, however, be divided into three general classes based upon the type of regulation used with the generator. At least one of each of these classes of wiring diagrams is reproduced here and familiarity with them will make it easy to trace the wiring of any system of this make.

Cadillac. Wiring diagram of the 1912 model is given in Fig. 244. Reference to a model as early as this is made to show the pro-

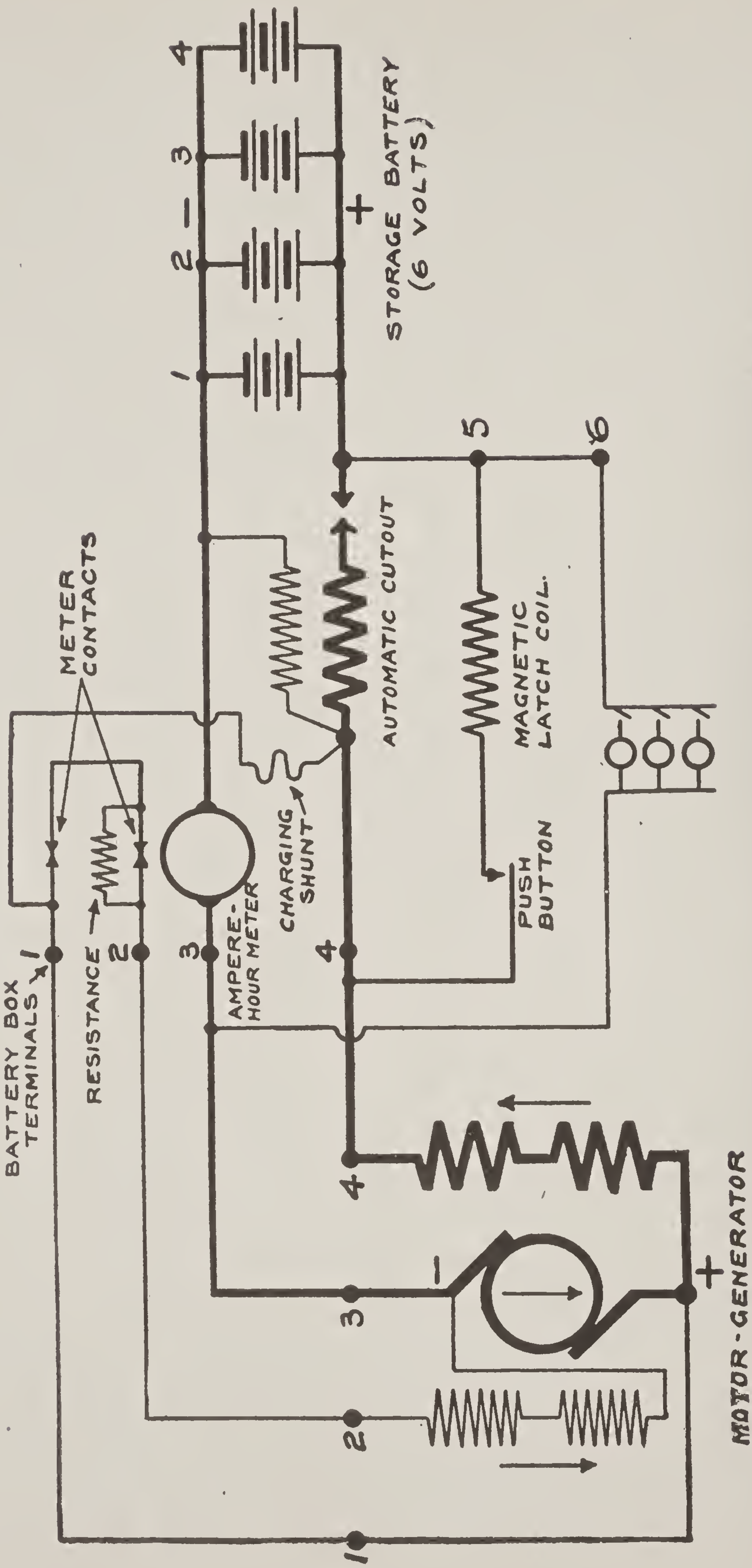


Fig. 244. Wiring Diagram for Generator Circuits of Delco Installation on Cadillac 1912 Models

gressive steps represented by each succeeding year; also because there are a great many of these cars still in use. Twelve cells of battery were employed though the dynamo generated current at 7 to 8 volts (nominally a 6-volt system), and as shown by the diagram which illustrates the connections of the generator circuit, the battery was divided into four groups of three cells each in series-multiple for charging. An ampere-hour meter showed the state of charge of the battery and also indicated how much current was consumed by the various circuits, including the starting motor. Regulation was by means of extra resistance inserted in the field circuit of the generator and an automatic battery cut-out was employed. The diagram shown in Fig. 244 is applicable to the connections of all the Delco 6—24-volt systems in use, when the machine

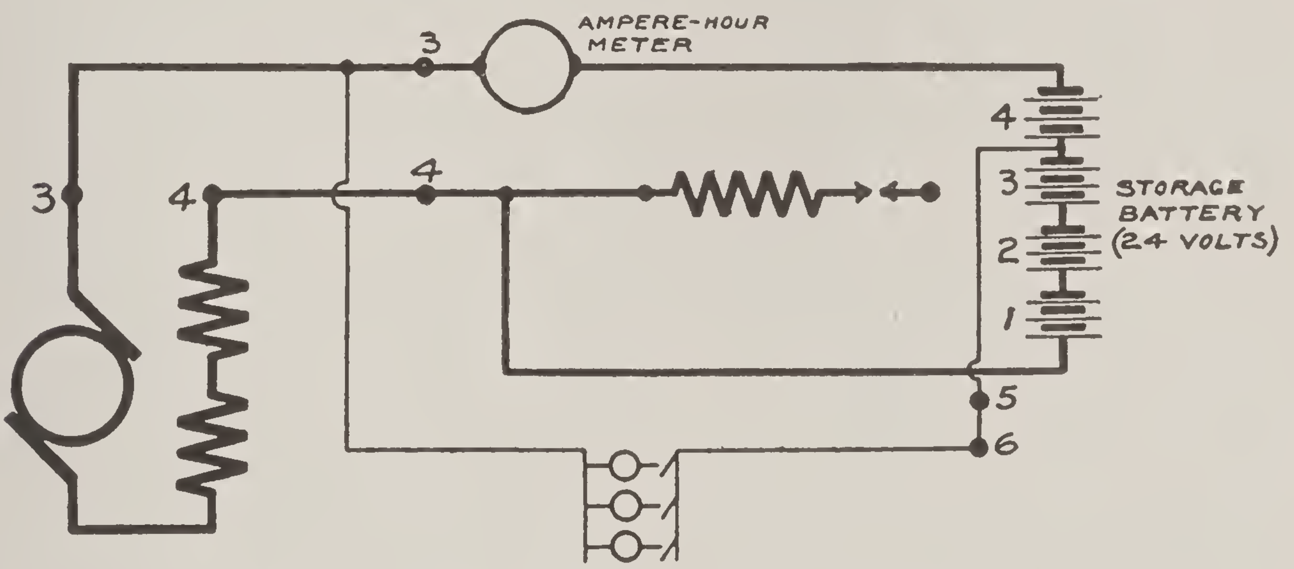


Fig. 245. Wiring Diagram of Starting Motor Circuit for All Delco 6—24-Volt Systems

is operating as a generator. The heavy lines indicate the main charging circuit. Fig. 245 shows the starting motor circuit of all the Delco 6—24-volt systems, and it will be noted that the cells of the battery are all in series to supply current at 24 volts, group No. 4 being utilized to supply current to the lamps at 6 volts.

Fig. 246 shows the wiring diagram of the Cadillac 1914 model. This is a straight 6-volt system, the generator being provided with the mercury type of voltage regulator previously described and an automatic battery cut-out. The starting-motor circuit is controlled by an external switch and the lighting circuits are protected by fuses. The earlier form of the combination switch controlling the ignition and the preliminary motorizing of the generator for starting, is seen at the right. The 1914 diagram is essentially the same, the chief

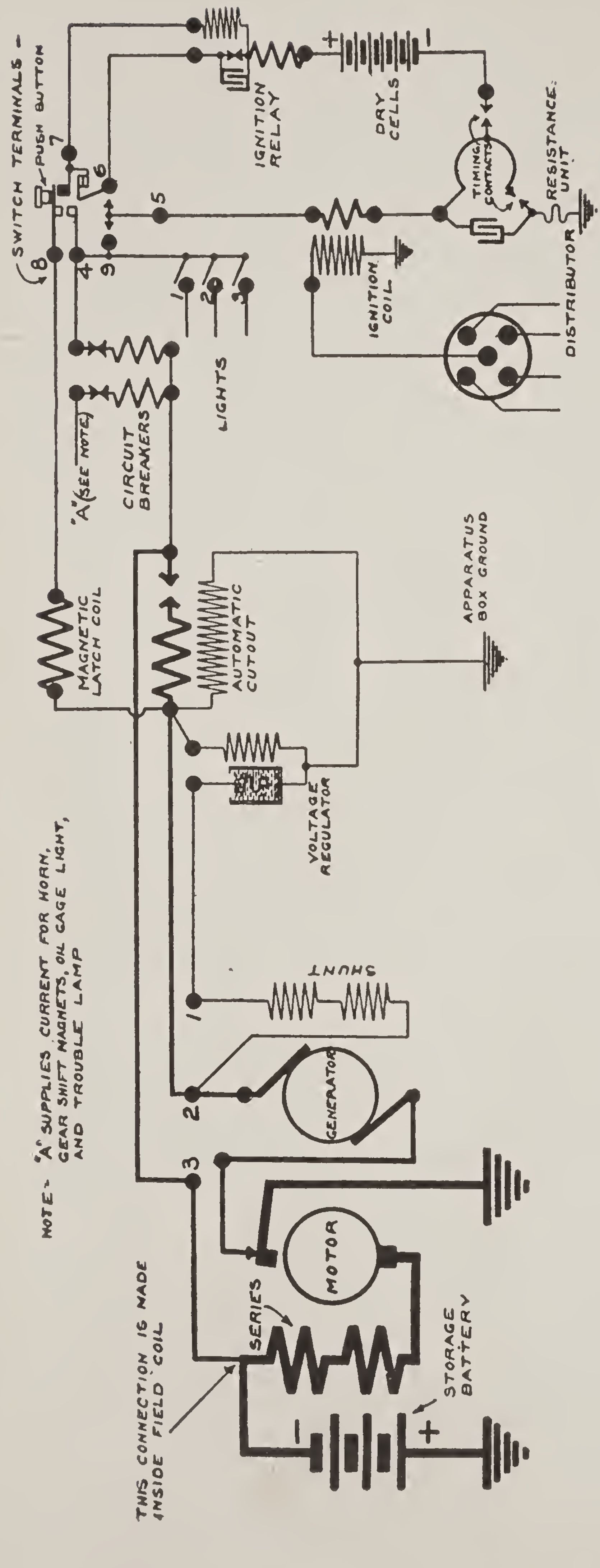


Fig. 246. Wiring Diagram for Delco System on Cadillac 1914 Models

difference being the substitution of the motor brush switch for the external switch controlling the starting motor. The fuses were also replaced by two circuit breakers, one for the main lighting circuits and ignition, and the other for the auxiliary lamps, horn, and the gear-changing solenoids, the model of that year being equipped with an electric magnetic gear shift in the transmission.

In the 1915 wiring diagram, Fig. 247, the method of regulating the generator has been changed to the mechanically varied resistance already described. One circuit breaker protects all fuses and a rotary form of combination switch controls all the circuits.

Buick. Two different types are employed on the 1915 models, the only distinction, however, being in the method of

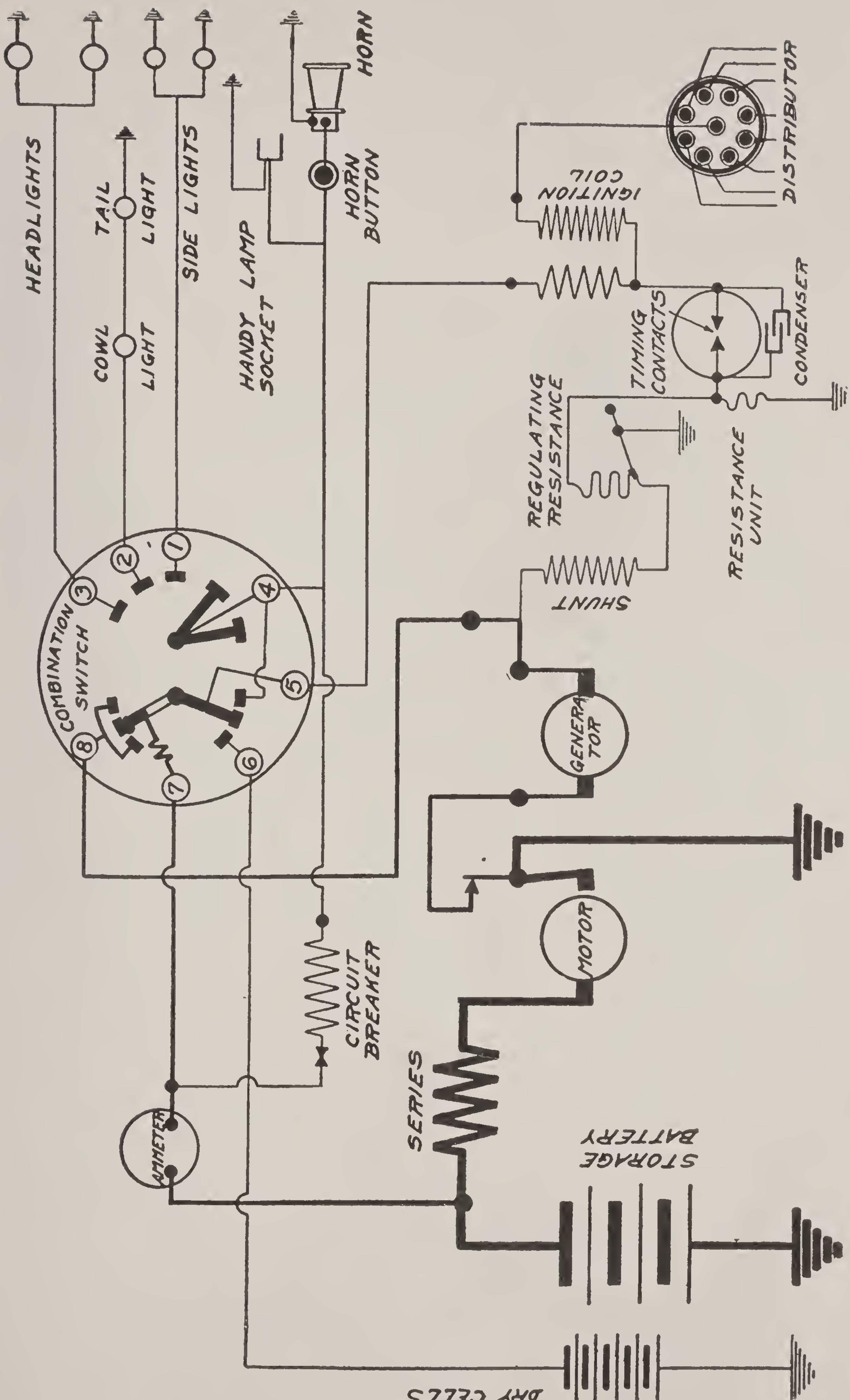


Fig. 247. Wiring Diagram for Delco System on Cadillac 1915 Models

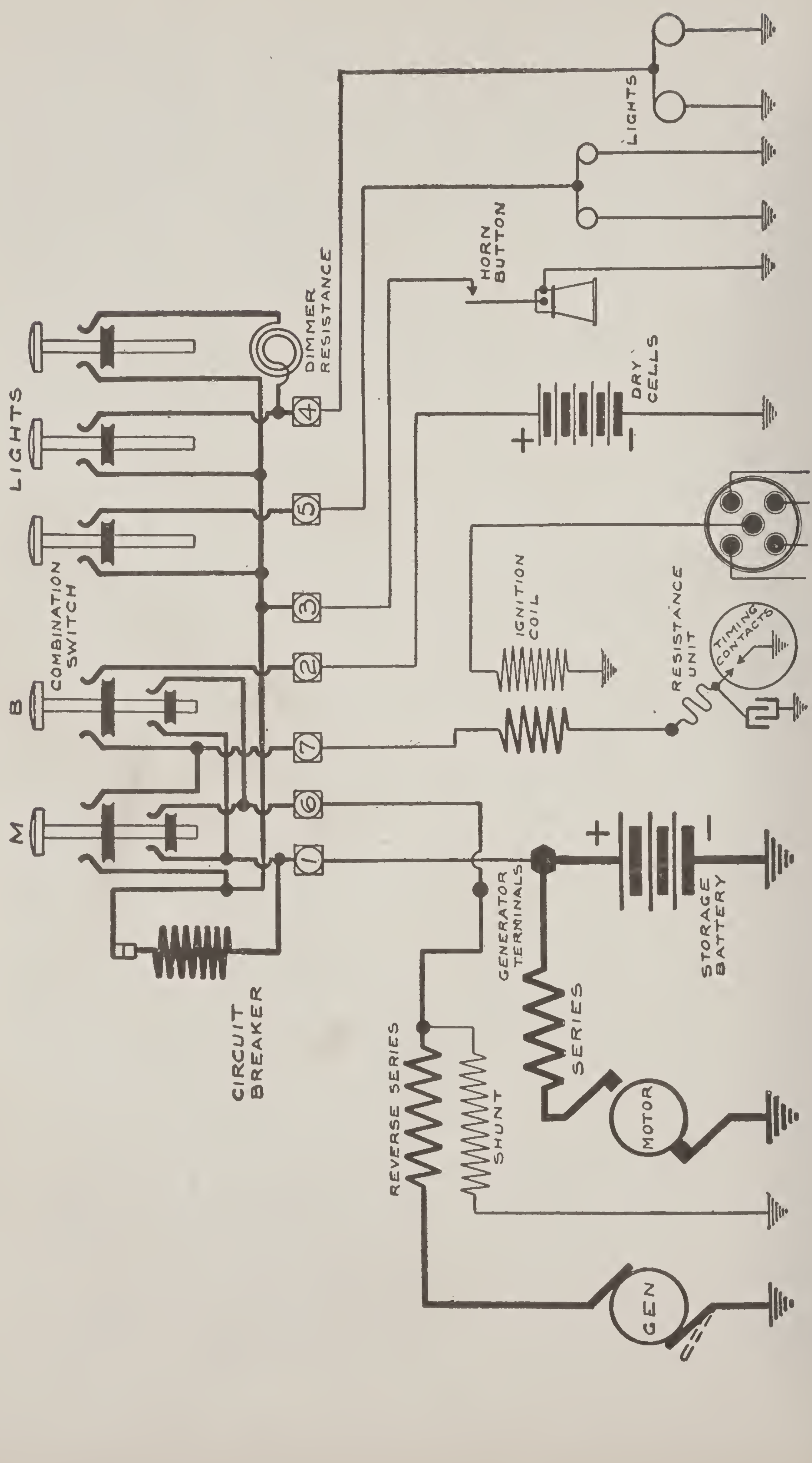


Fig. 248. Wiring Diagram for Delco Installation on the Buick Models C24 and C25

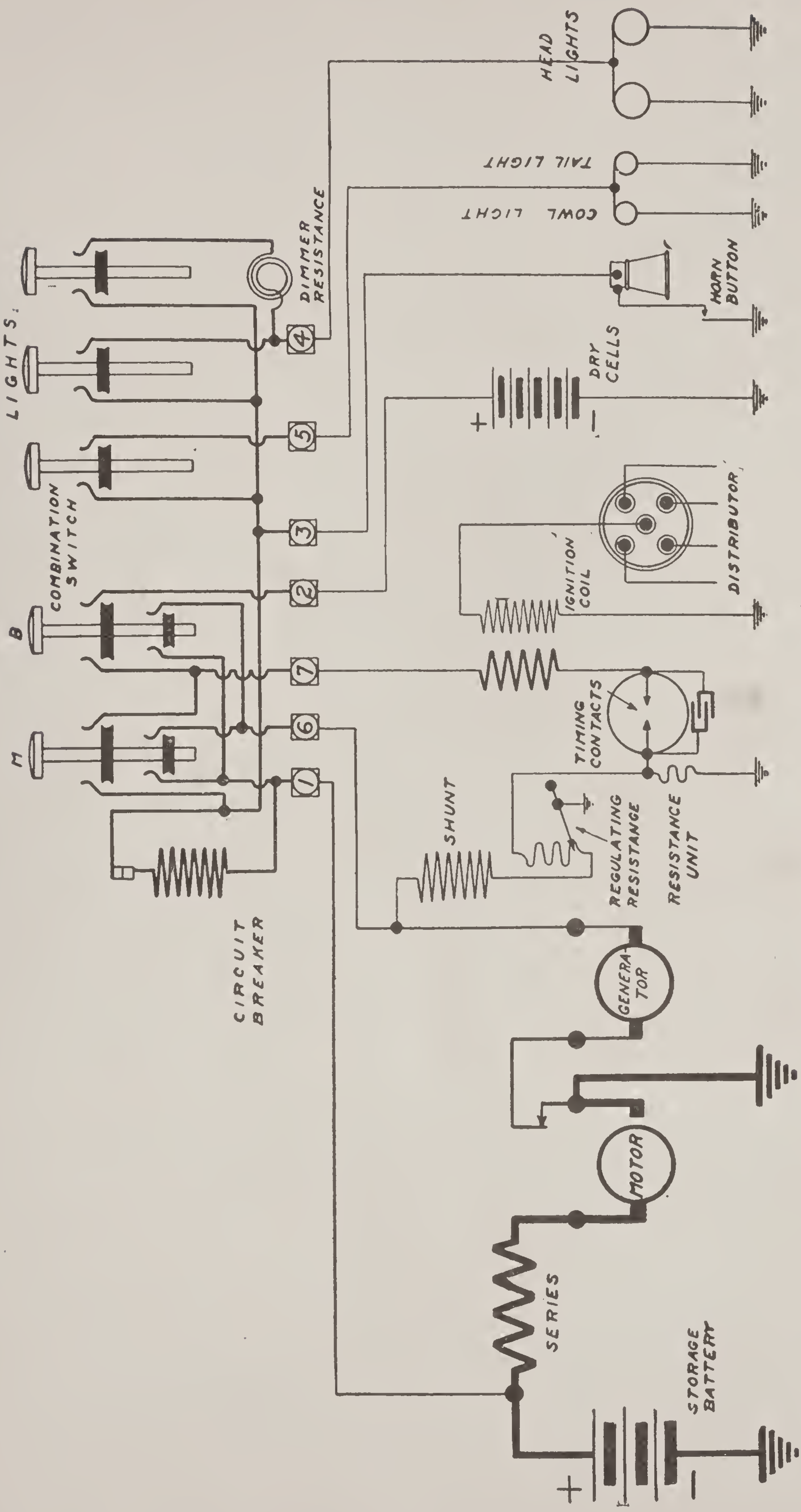


Fig. 249. Wiring Diagram for Delco Installation on Buick Models C36 and C37

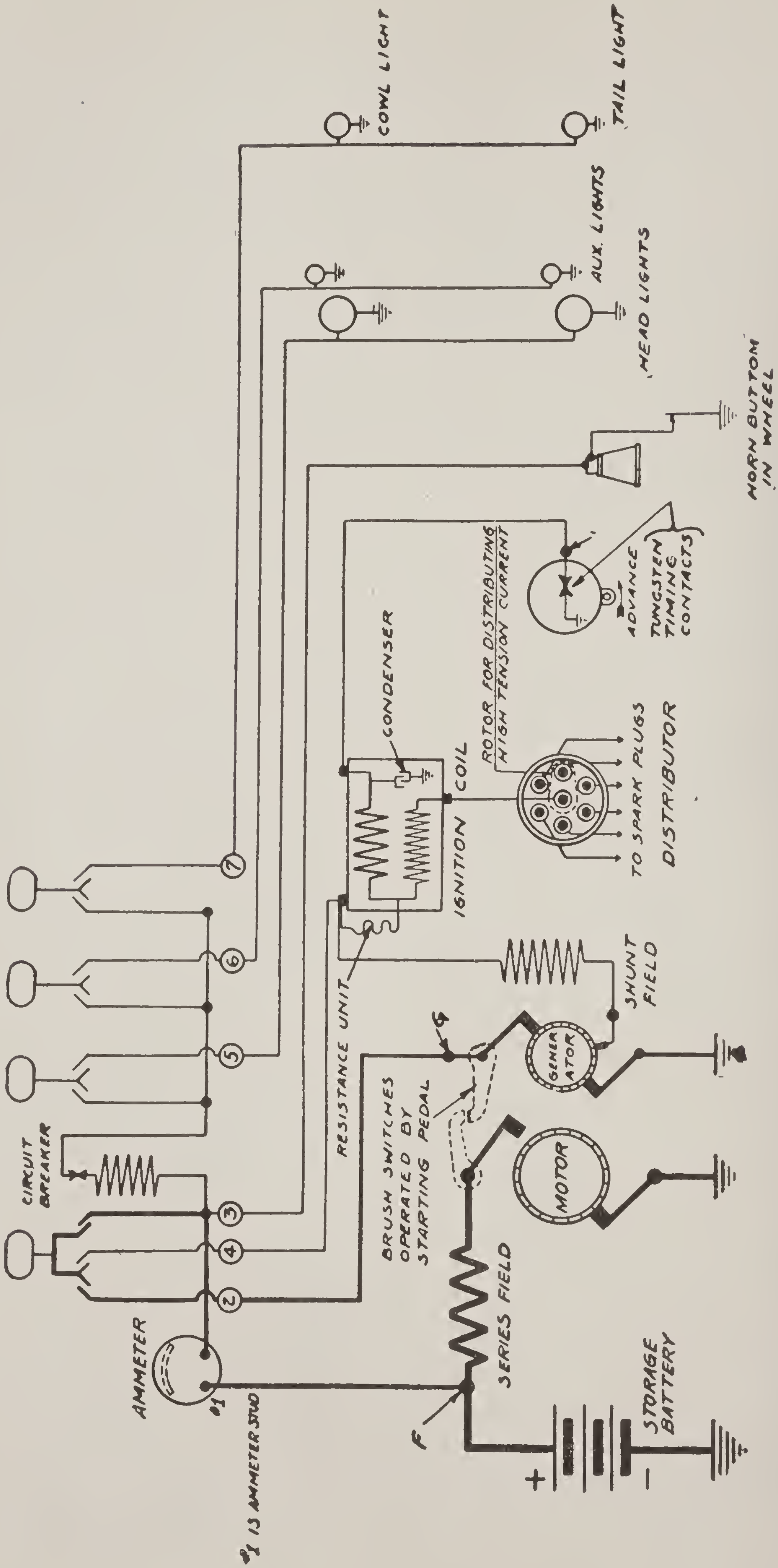


Fig. 250. Wiring Diagram for Delco Installations on Buick 1916 Models

generator regulation. That of Models C24 and C25 is by means of the reversed series-field winding or bucking coil, while that of Models C36 and C37 utilizes the mechanically varied resistance or rheostat operated by a centrifugal governor, as shown in Fig. 249. The buttons *M* and *B*, in each instance, control the ignition circuit, depending upon whether the storage or the dry battery is called upon for the ignition current as well as for the current to motorize the generator preliminary to starting. The remaining three buttons of the combination switch control the lights and dimming resistance and it will be noted that the circuit-breaker forms a part of every one of the circuits except that of the starting motor.

On the 1916 Buick models, the generator is regulated by the third-brush method; the brush switches are operated by the starting pedal; only the lighting circuits are protected by the circuit-breaker, and an ammeter is inserted in the circuit with the latter, Fig. 250. No mention is made of the details of any of the ignition circuits in these diagrams as that is taken up in the section on Ignition. Apart from the fact that the Oakland Model 50 has a 4-pole motor winding instead of the bipolar type shown in all the previous diagrams, the wiring diagrams of the Oakland models for 1916 are the same as those shown for the Buick. On the two 1915 models of the Cole, the distinction between the wiring diagrams is the same as that mentioned for the two classes of Buick models of the same year, i.e., one having the reversed series field, and the other the variable resistance controlled by the governor—the combination switch, circuit-breaker, and other connections of the diagrams being essentially the same.

Six-Volt; Two-Unit; Single-Wire

Generator. This generator is a bipolar machine of the shunt-wound type, a section of which is illustrated in Fig. 251. As installed on the Westcott (1917)—a wiring diagram of this installation being illustrated in Fig. 255—the generator is driven from the water-pump shaft through a one-way clutch, that is, a type that will drive when turned in one direction but will run free when driven in the opposite direction. This permits the generator armature to revolve when the engine is not running, thus preventing a heavy current discharging through the generator from the battery when the ignition switch is turned on while the engine is idle. This is due to the fact that the

same switch which closes the ignition circuit puts the generator in circuit, as explained in connection with the wiring diagram. If the generator armature could not revolve, its resistance would be very low, so that a heavy discharge would take place, but as it is permitted

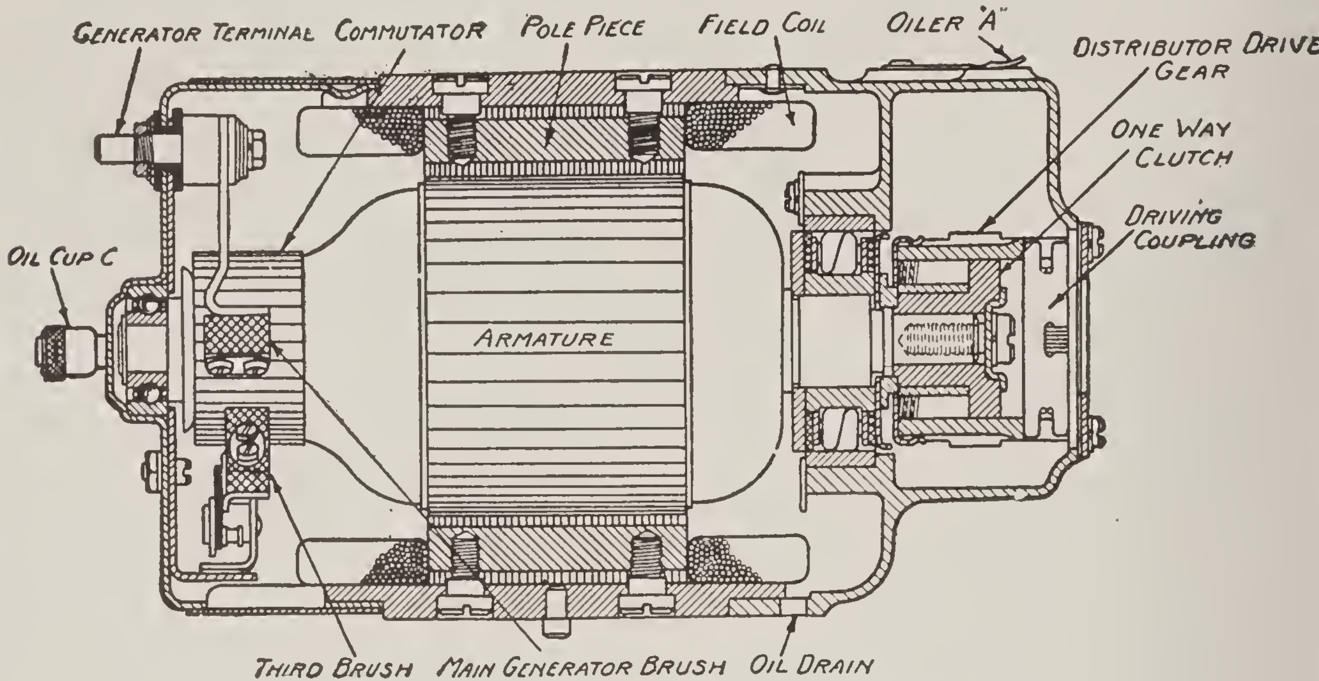


Fig. 251. Generator of Delco Two-Unit System
Courtesy of Dayton Engineering Laboratories Company, Dayton, Ohio

to become *motorized,* its armature builds up a strong counter e.m.f., as explained under Electric-Motor Principles, Part I, thus greatly increasing the resistance and greatly decreasing the amount of current that will pass through it.

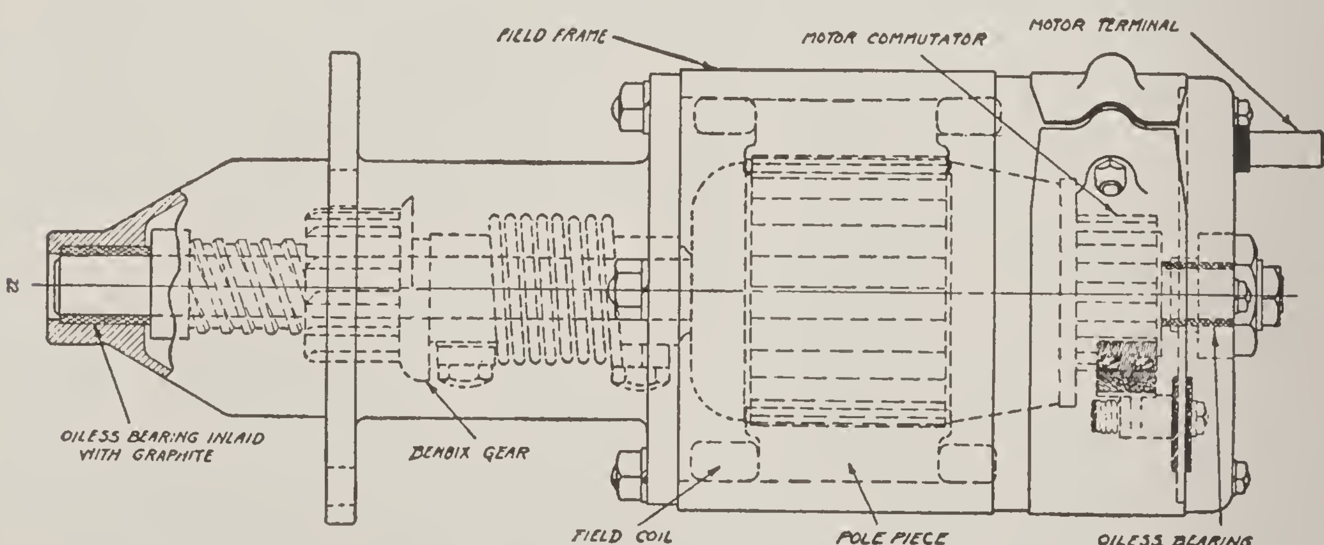


Fig. 252. Diagram of Starting Motor for Delco Two-Unit System

Regulation. The regulation is of the third-brush type, which has already been explained in detail in connection with the single-unit Delco system.

Starting Motor. Fig. 252 shows a longitudinal view of the starting motor fitted with the Bendix drive, while an end view of the motor,

illustrating the commutator and brushes, is shown in Fig. 253. This motor is of the multipolar type, and its method of control differs from the single-unit type in not employing the brush switch.

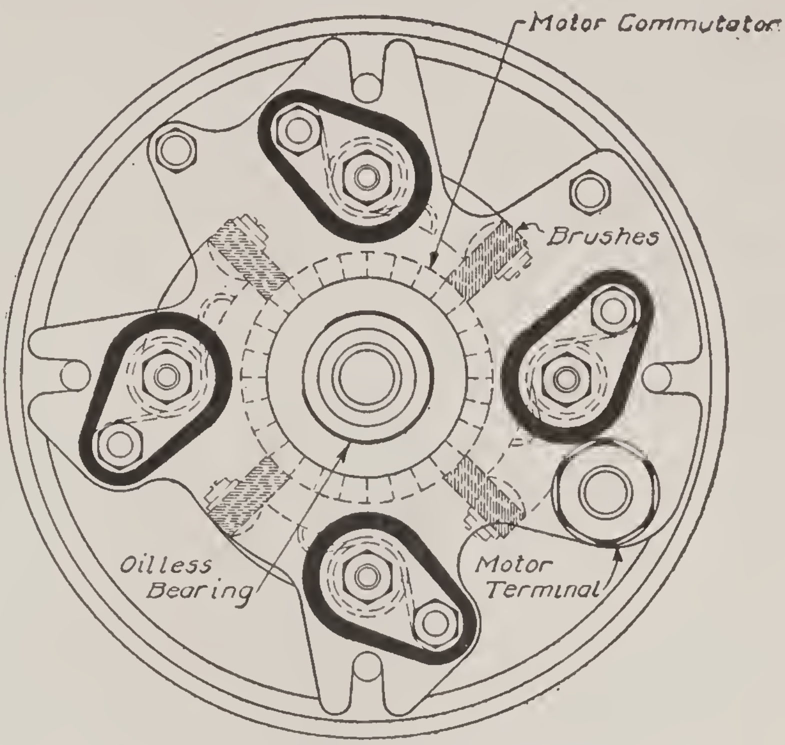


Fig. 253. End View of Delco Starting Motor, Showing Commutator and Brushes

Starting Switch. A pedal-operated plunger type of switch is employed, for which the advantage is claimed that its contacts are self-cleaning. The method of effecting this will be apparent from the part-sectional view of the switch, Fig. 254. The switch is in barrel form, with the springs incorporated in the plunger, while the stationary and movable contacts are given a contour that causes them to scrape against each other when coming into contact, thus keeping these surfaces bright.

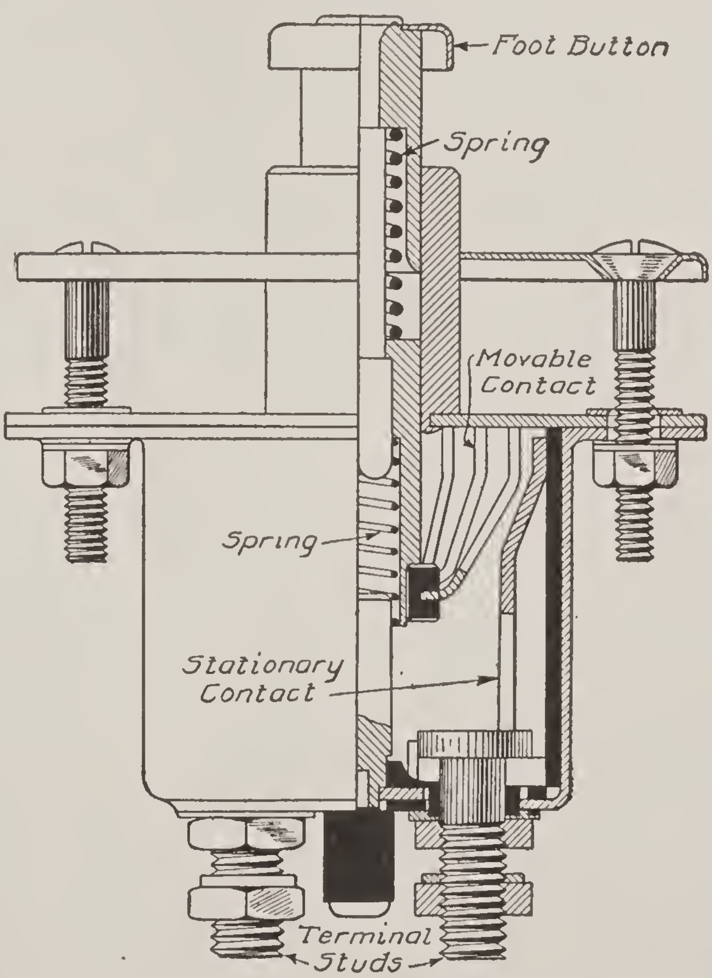


Fig. 254. Part Section of Delco Starting Switch

Wiring Diagram. By comparing this wiring diagram, Fig. 255 with Fig. 250, which shows the single-unit Delco system as installed on a Buick machine, a clearer idea of the difference in the requirements of the single- and two-unit sets, where their circuits are concerned, will be obtained. It will be noted that the connections of the lamps, ignition, and horn are the same, though the method for

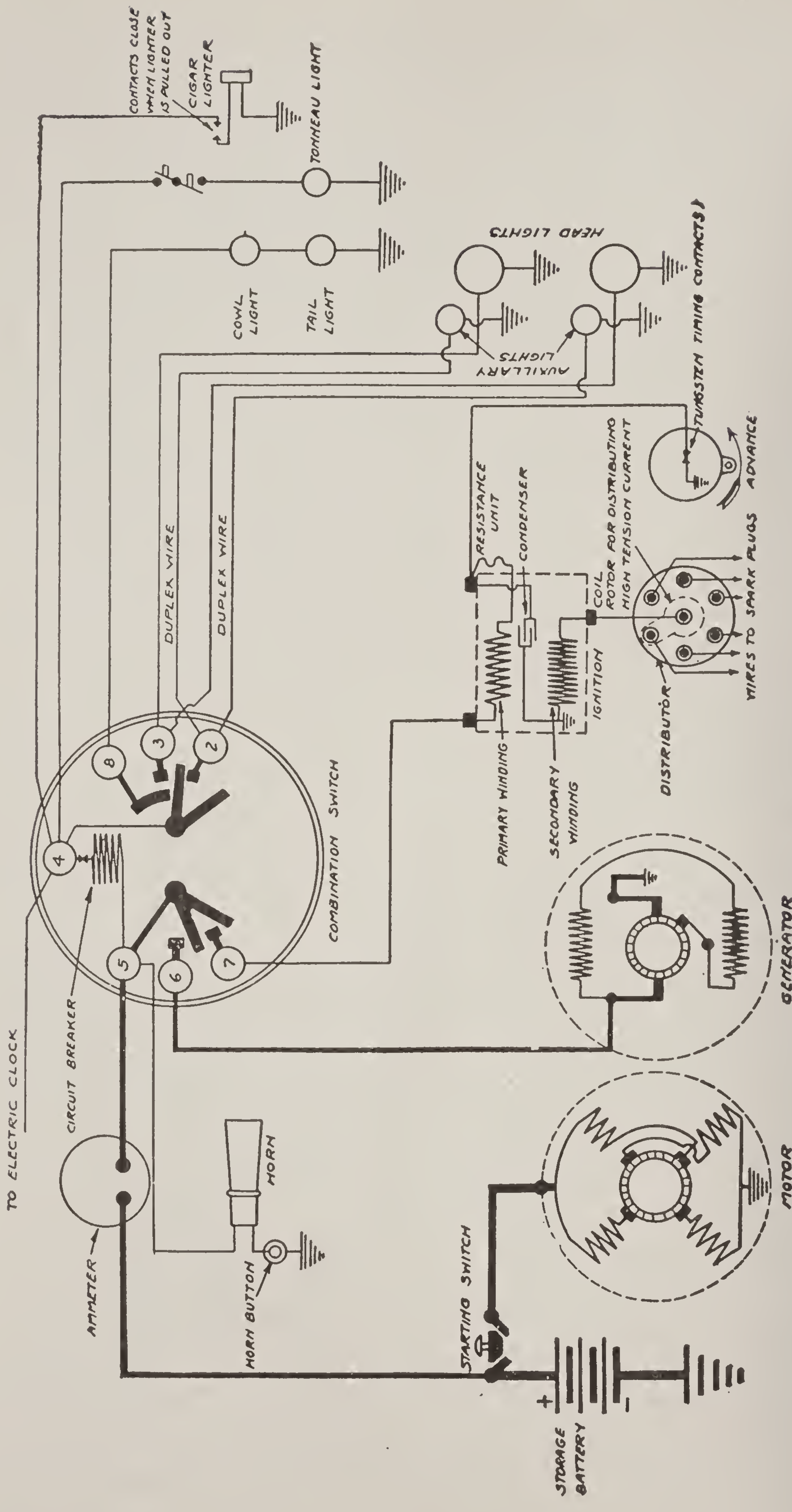


Fig. 255. Complete Wiring Diagram of Delco System on 1917 Westcott Cars

controlling them differs. Likewise that all of these, with the exception of the ignition, are protected by the circuit-breaker. The lighting circuits appear more complicated simply because there is an extra light (tonneau light) and two additional accessories, i.e., a connection for an electric cigar lighter and one for an electric clock.

The chief difference is in the generator and the starting-motor circuits. An unusual feature in this essential is a two-part switch member which controls the ignition and the generator circuits. By this method, opening the ignition switch opens the circuit between the storage battery and the generator, so that a battery cut-out is dispensed with. There is, even under the most favorable conditions, a perceptible interval between the closing of the ignition switch and

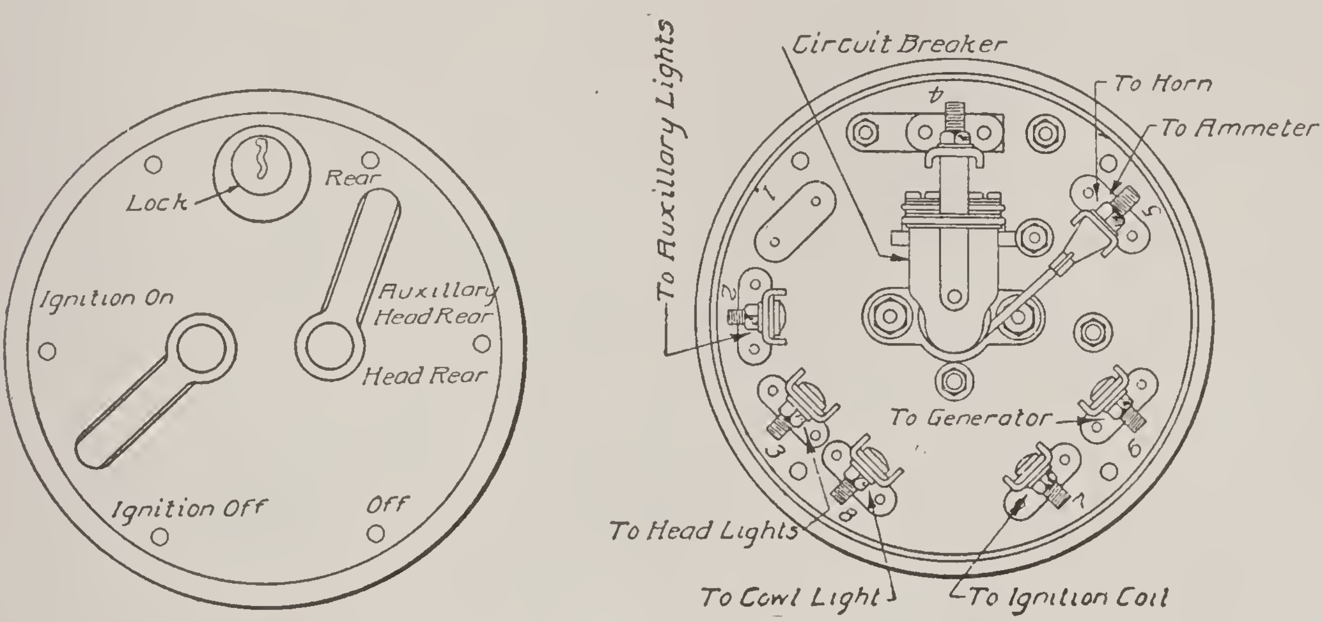


Fig. 256. Front and Reverse Face of Combination Switch for Delco Two-Unit System

the starting of the engine, and in winter this may be increased to a considerable period, during which there will be a heavy discharge from the battery through the generator, unless means to avoid it be provided. The way this is accomplished is by the employment of a one-way driving clutch on the generator, as already described. When running, the generator is driven by the pump shaft of the engine in one direction; when the battery current passes through it, it is free to run as a motor in the opposite direction, despite the fact that the engine is idle. While operating as a motor, its resistance is sufficiently high to cut this discharge from the battery to negligible proportions. As soon as the engine starts, the generator is driven in the opposite direction, and its voltage immediately overcomes that of the battery, and the battery begins to charge.

The face of the starting switch and the details of the connections on its reverse are shown in Fig. 256.

Delco Instructions

General Instructions. If the starter, lights, and horn all fail, the trouble is in the storage battery or in its connections, one of the connections being loose or corroded, or one of the battery jars being broken. When the lights, ignition, and horn all work normally but the starter fails to operate, the trouble is in the motor-generator, or dynamotor, and may be caused by the motor brush switch not dropping on the commutator, or by dirt or grease on the commutator. Owing to the heavy current required by the motor in starting, if the lights are on at the time, they will become dim when the starting circuit is closed but remain so only momentarily. In case they go out or become very dim when the starting-motor circuit is closed, it indicates that the battery is practically depleted. When the motor fires properly on the *M* button of the combination switch, but not on the *B* button, the wiring between the dry cells or the connection from the dry cells to the combination switch must be at fault. When the ignition works all right on button *B*, but not on *M*, the trouble must be in the leads running from the storage battery to the generator, or in the lead running from the small terminal on the generator to the combination switch, or in the battery connections, either of the cells themselves or the ground connections. If the supply of current from both the dry cells and the storage battery is ample, yet both ignition systems fail, trouble should be sought first at the timer contacts, then the coil, resistance unit, and the condenser. An examination of the timer contacts will show whether they are clean, square, and in good working condition; if badly burned and pitted, true them up square with a strip of fine emery cloth or a very fine flat file. The coil, resistance unit, and condenser may be tried out with the test-lamp outfit. If the lamp lights when contact is made through the terminals of the coil or the resistance unit, it indicates that nothing is wrong with them, but if it lights on the condenser it shows that the insulation of the latter has broken down, as there should be no circuit through the condenser. The only remedy is to replace it. All of the units mentioned work in the same capacity for each system of ignition.

If, for purposes of making tests, it becomes necessary to remove any of the electrical apparatus from the car, or to make any adjustments, the storage battery should first be disconnected. This can be done most conveniently by removing the ground connection and winding the bare terminal with electrician's tape so that it cannot come in contact with anything that would cause a short-circuit. The car should not be run with the storage battery disconnected

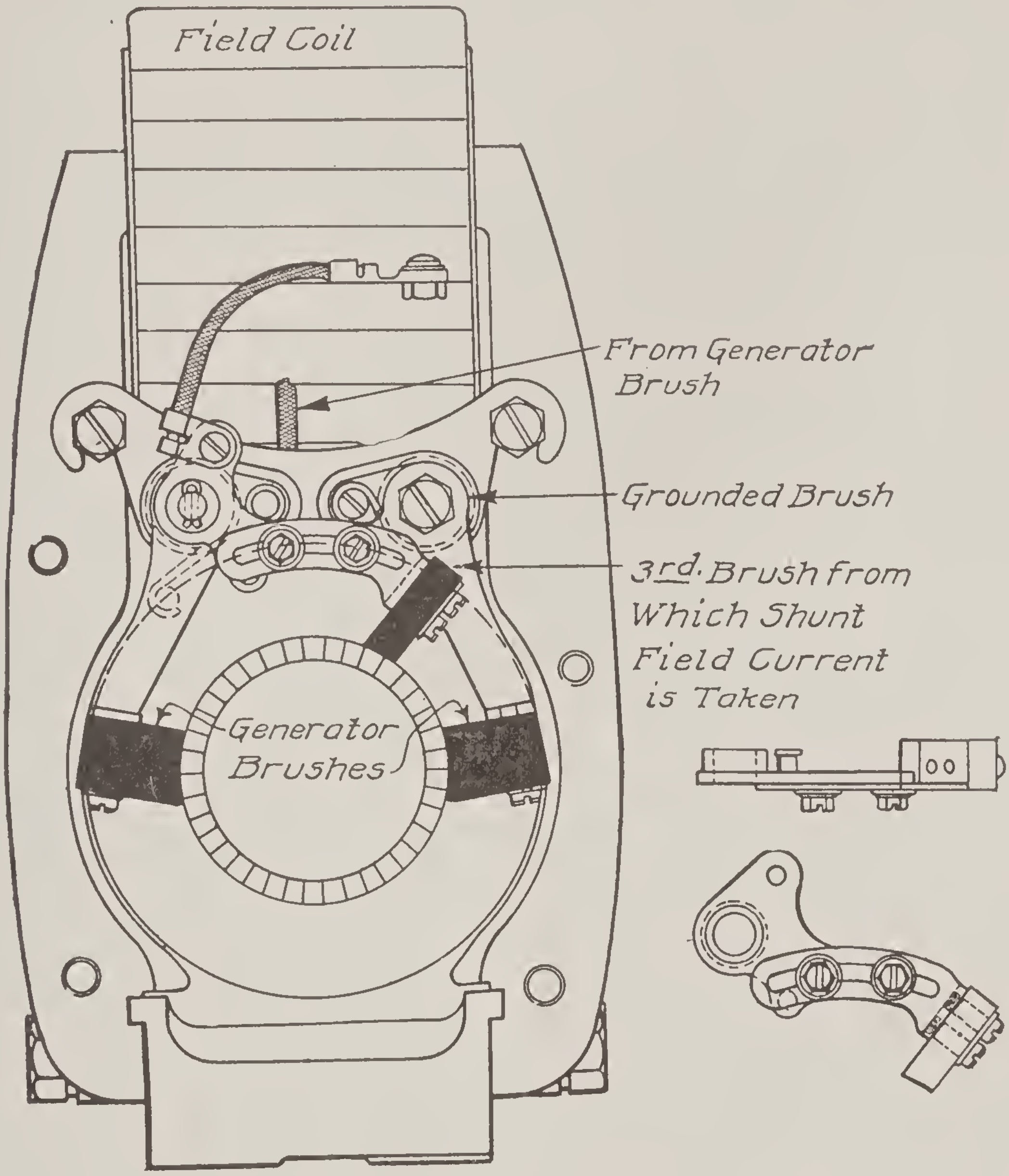


Fig. 257. Diagram Showing Method of Adjusting Third Brush in 1916 Delco Generator

from the generator or with the battery off the car unless the generator is short-circuited, as otherwise serious damage may result, as the generator is likely to be burned out.

Adjusting Third Brush. One of the advantages of the third-brush method of regulation is the ease with which the output of the generator may be varied. It has been found that on some of the 1916 models of the Delco system the generating capacity (as adjusted at the factory) has been set too high, especially for cars which are

driven a great deal during the day and very little at night. As a result, considerable more current is generated than can be used to advantage. An indication of this will be found in the frequent necessity for adding water to the cells of the battery, or the fact that the battery is constantly gassing. In a case that recently came to the writer's attention, the owner of the car complained that the battery was no good because it was always *boiling.* It boiled so continually and so violently that it eventually had to be replaced. The complaint, in the average case, is that the battery is undercharged rather than overcharged. Unless trouble is experienced because of the battery gassing too much or needing water too frequently, the charging rate should not be altered. When necessary, the alteration may be made as follows: It will be noted in Fig. 257 that the third brush is carried on a brush arm made in two pieces and that the part to which the brush is fastened has a slot through which pass two screws, attaching it to the other part. By loosening these screws, one part may be slid on the other, thus increasing or decreasing the length of the arm. When the arm is shortened, the charging rate is decreased; and when the arm is lengthened the charging rate is increased. Care should be taken to sand-in the brush whenever it has been shifted in order to insure good contact with the commutator. (See Instructions for Seating Generator and Motor Brushes.) The screws on the brush arm must be firmly tightened after adjusting to prevent slipping.

The charging rate of this type of Delco generator is higher at low-car speeds than on some machines of an earlier type, so that the maximum should be kept somewhat below the value that would be used for earlier machines. In most cases 14 to 16 amperes will be ample, and in no case should it exceed 20 amperes. Readings should be taken at the ammeter on the cowl switch, which indicates the amount of current going to the battery but does not include the ignition current.

The foregoing instructions for altering the charging rate apply only to machines having the third brush mounted on an adjustable arm, as different methods of moving the brush are provided on other types. The principle of adjustment, however, is always the same, i.e., moving the third brush closer to the nearest main brush increases the output and moving it away from this brush, decreases it. The third brush must never be allowed to come in contact with the main

brush. In the case of the Delco generator under consideration, the charging rate should reach a maximum at a speed of 15 to 20 miles per hour and then drop off as the speed increases beyond this point.

Tests of Wiring. *Locating Grounds.* By referring to any of the Delco diagrams of the one-wire type, it will be noted that certain parts of the circuits are normally grounded, i.e., they are connected to the common return represented by the chassis of the car. For example, the negative battery terminal, one terminal of each lamp, one motor, one generator brush, one timer contact, one terminal of the horn push button, and one terminal of the condenser in the coil are grounded. Before testing the wiring for grounds, it will accordingly be necessary to remove these normal, or intentional, grounds. This is carried out, in the order in which they are mentioned, by disconnecting the negative battery lead and removing all the lamps, placing a piece of cardboard between each generator and each motor brush, including the third brush of the former and the commutator against which it ordinarily bears, disconnecting the leads from the horn button and from the distributor, and raising the base of the ignition coil so that it is insulated from the top cover of the generator motor. The system will then be in the condition shown in Fig. 258.

One of the test points is then placed on the frame of the car and the other point on the negative terminal *A* of the battery. If the lamp lights, it will indicate a ground somewhere on the switch or in the motor windings (all of the switch buttons being pushed in). Then, with one test point still grounded on the frame of the car, test with the other point the different terminals of the combination switch. If the lamp lights during this test, it will indicate a ground on that particular circuit, which can be remedied without any particular difficulty.

Locating Shorts. To test for short-circuits between wires that are normally insulated from each other, place one test point on the end of one wire and the second test point on the end of the other, as shown in Fig. 259. If the lamp lights, it will indicate a short-circuit between these two wires, which can then be carefully inspected to locate the exact position of the fault. Failure of the lamp to light when the test is made will indicate that the wires in question are in good condition; the tests can then be applied to other parts of the circuits which should be insulated from each other.

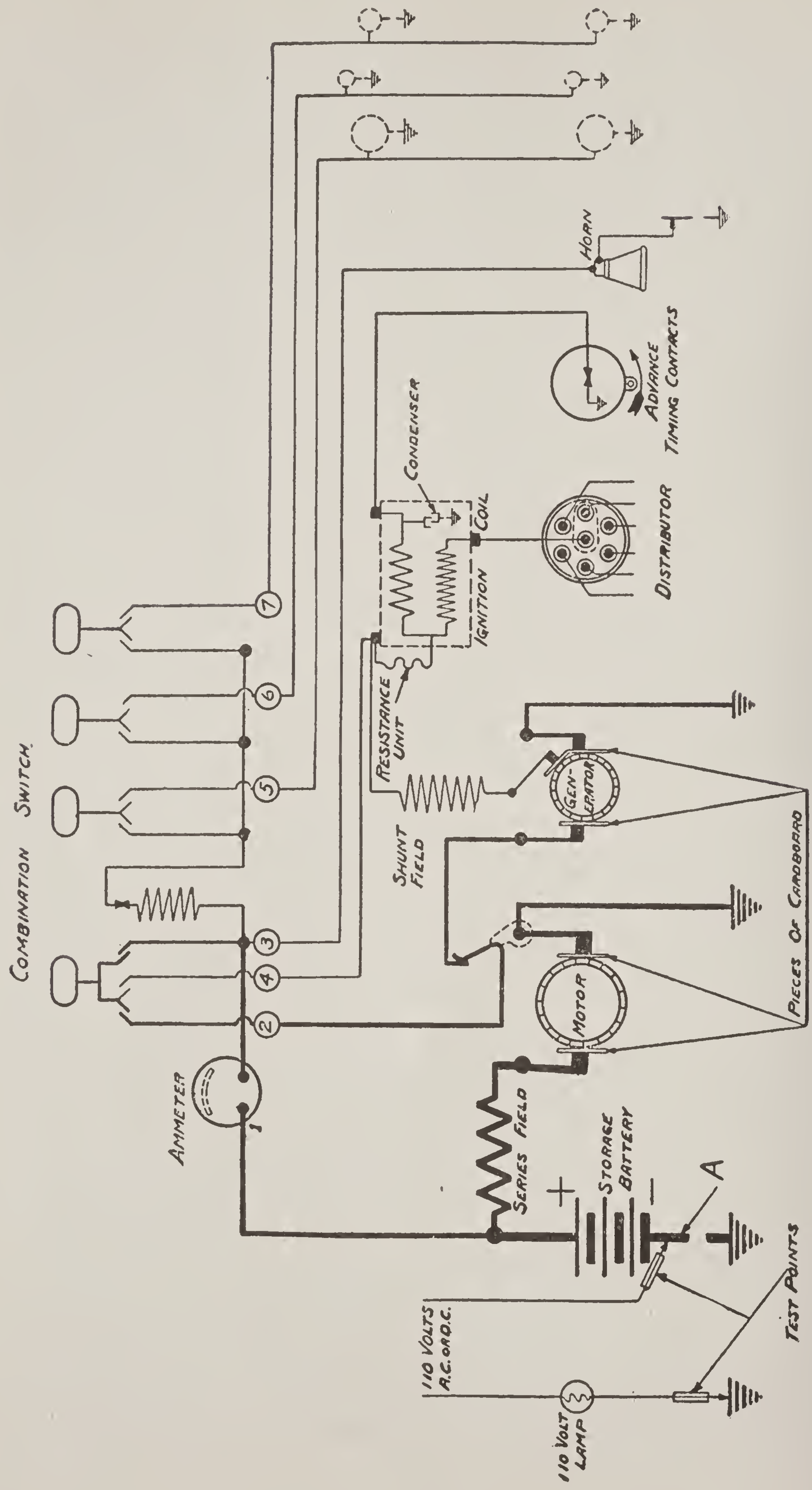


Fig. 258. Wiring Diagram Showing Method of Using Lamp-Testing Set for Locating Grounds
Courtesy of Dayton Engineering Laboratories Company, Dayton, Ohio

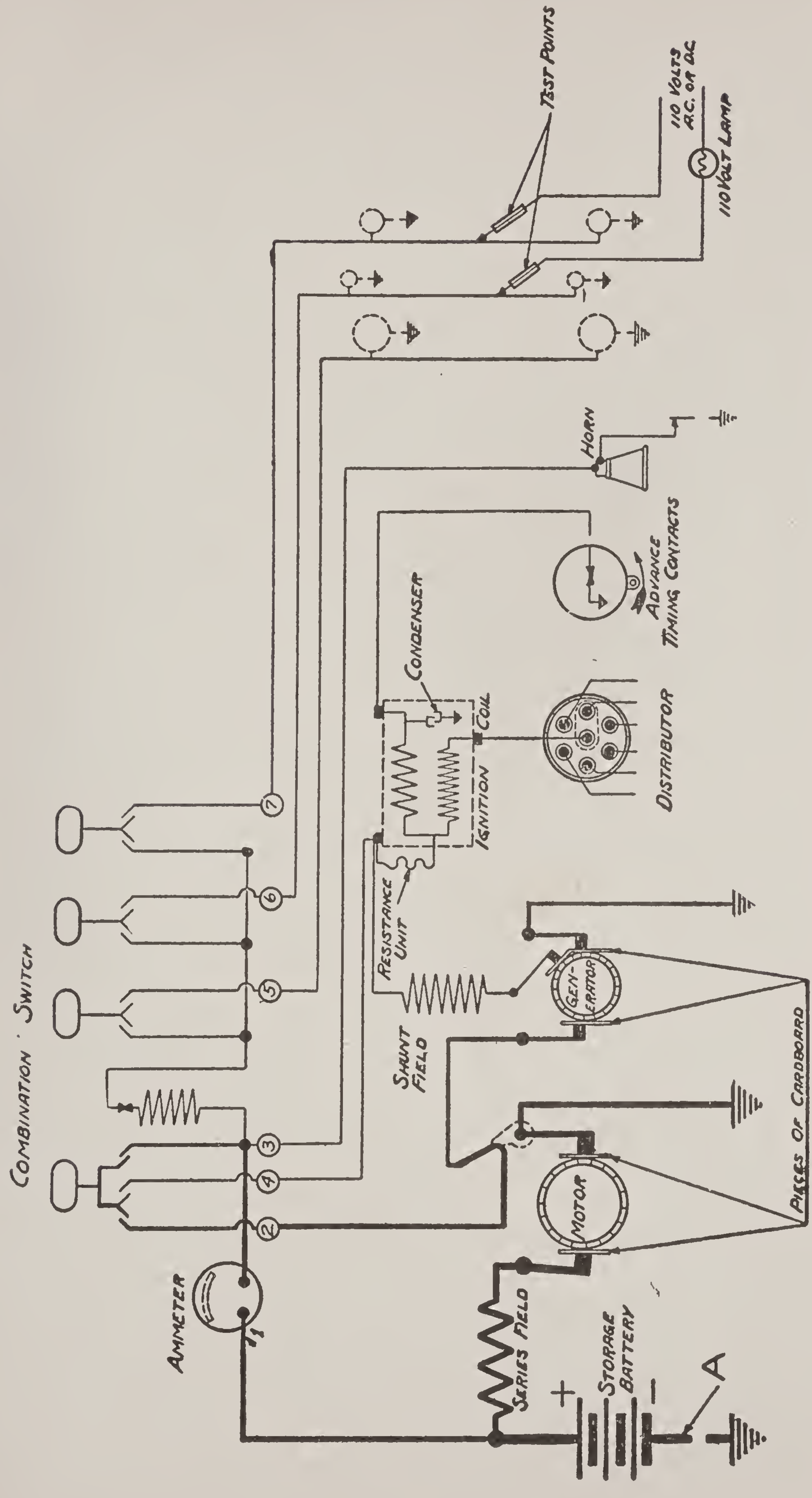


Fig. 259. Wiring Diagram Showing Method of Using Lamp-Testing Set for Locating Short-Circuits
Courtesy of Dayton Engineering Laboratories Company, Dayton, Ohio

Locating Breaks in Wires. Where the failure of the apparatus in a particular circuit makes it apparent that a wire, or lead, may be broken, it may be tested by placing one of the points on each end of the wire in question. The lighting of the lamp will indicate that there is a complete circuit through the wire, while its failure to light is evidence of a break in the wire. If at all difficult to locate the break, the easiest method of repairing it is to replace the wire with a new lead of the same size and type of insulation. The method of carrying out this last test is illustrated in Fig. 260 and it is naturally applicable to any of the wires, not only of this type of installation but of any other lighting and starting system. In making this test, care must be taken not to apply the points at places on the terminals where a ground connection will result, as this will complete the circuit through the lamp without the current passing through the wire supposedly under test. This method of locating grounds, short-circuits, or open circuits will be found much better than the use of a buzzer, bell, or magneto, and it is recommended wherever a 110-volt current is available. However, where it is not available, a lamp, bell, buzzer, or the portable voltmeter may be used in connection with the storage battery on the car, after detaching its usual connections to the system.

Testing Cut-Out. If the battery is not charging properly, the generator being in good condition, or it is discharging too much current through the cut-out, the latter should be tested and adjusted to remedy the trouble. The cut-out is designed to close when the voltage across the terminals of the voltage coil is $6\frac{1}{2}$ to $7\frac{3}{4}$ volts. To check this a voltmeter should be connected across the terminals, noting the reading at the point that the contacts close. It is designed to break the circuit when the discharge current is less than 1 ampere, preferably as close to the zero mark as possible to reduce the arc on breaking the contacts. This can be checked by placing an ammeter in the circuit in series with the current coil of the cut-out, noting the value of the current at the moment that the contacts separate. When properly adjusted the air gap should be $\frac{1}{32}$ inch.

To adjust the cut-out, the influence of both the air gap and of the spring tension must be taken into consideration. The air gap has little or no effect upon the point of cut-out, this being governed almost entirely by the spring tension, whereas the point of cutting

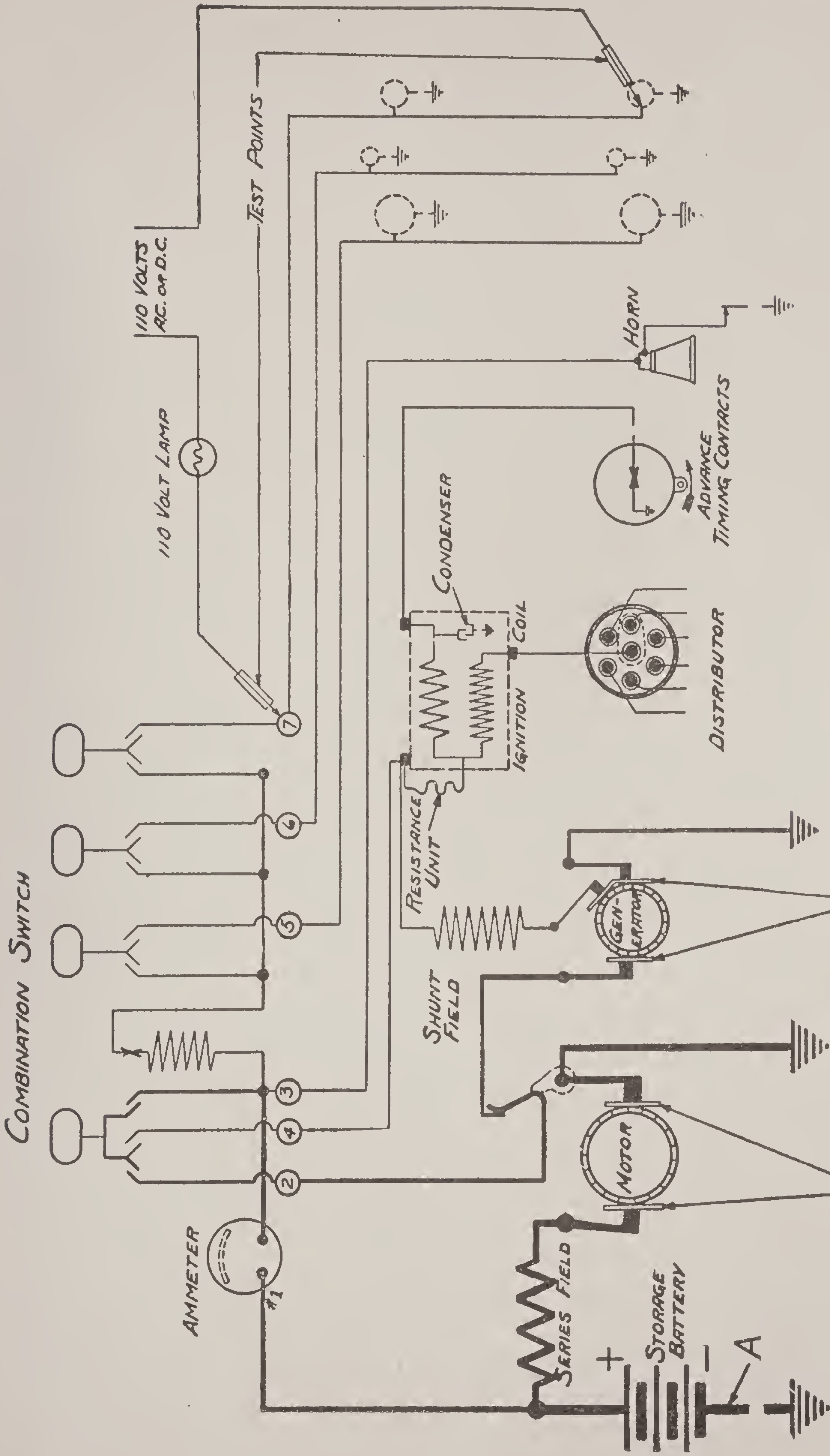


Fig. 260. Wiring Diagram Showing Method of Using Lamp-Testing Set for Discovering Breaks in Wires
Courtesy of Dayton Engineering Laboratories Company, Dayton, Ohio

in is governed by both the air gap and the spring tension. The following examples will illustrate the adjustments necessary in cases of excess voltage and current, excess voltage alone, insufficient voltage and excess current, and insufficient voltage alone.

Where the relay cuts in at 8 volts and cuts out when the discharge current is 2 amperes: Decrease the air gap, as this will lower the voltage of the cut-in point, but it will also increase the discharge current on cutting out. To overcome the latter, increase the spring tension slightly, noting the effect on the ammeter until the latter registers less than 1 ampere on cutting out.

Where the relay cuts in at 8 volts and cuts out at 1 ampere: Decrease the spring tension as this will cause the relay to cut in at a lower voltage and also to cut out after the current starts to discharge through it.

Where the relay cuts in at 6 volts and cuts out at 2 amperes: Increase the spring tension, causing the relay to cut in at a higher voltage and also to cut out at a discharge-current value of less than 2 amperes.

Where the relay cuts in at 6 volts and cuts out with a discharge current of 1 ampere: Increase the air gap slightly and also increase the spring tension so as to cause the relay to cut in at a higher voltage and also cut out at a discharge current of less than 1 ampere.

In this connection *cut in* signifies the closing of the contacts when the voltage coil becomes energized as the generator starts up; *cut out* indicates the opening of the generator battery circuit when the current from the battery reverses the polarity of the current coil of the relay, thus opening the circuit and cutting out the generator from the battery circuit when the generator slows down and there is insufficient voltage for charging the battery. While these instructions apply particularly to the Delco relay or cut-out, all devices of this nature operate on the same principles.

Before making any adjustments, the contact points should be examined. If they are blackened or pitted, take two narrow strips of emery cloth about $\frac{3}{8}$ inch wide and both the same length. Place them together, emery sides out, insert between the contacts and while an assistant holds the points together, draw back and forth. If no assistance be obtainable, use a single strip and apply alternately to each contact point until its face is bright all over and true

so that when the two points come together they touch evenly all over their surfaces. Do not take off any more than is necessary for this purpose, particularly where the contacts are platinum, as this simply wears them away uselessly and they are very expensive to replace. After cleaning, test for cutting in voltage and cutting out current and it frequently will be found that no adjustment is necessary.

These instructions regarding the cleaning of contact points apply with equal force to all instruments having contacts by means of which the circuit is frequently made and broken, for even platinum is burned away by the electrical action of the current which tends to carry the metal of the positive contact over to the negative in finely divided form, thus making a hole, or crater, on the positive and a cone, or peak, on the negative.

If the contacts are too badly burned to permit of their being put in good condition in this way, it will be necessary to replace them. After the relay has been reassembled with the new contacts, it should be adjusted in accordance with the instructions already given. When the contacts are correctly adjusted, both pairs will make contact at the same instant and clear across the line of contact so that when the relay is held up to the light, it is impossible to see light passing through any portion of the line of contact. When adjusting the relay make sure that all insulating bushings are in good condition and that the connections and coil terminals are free from breaks or grounds, as these would cause uncertainty in its operation.

Testing Circuit-Breaker. In case the circuit-breaker vibrates constantly, it indicates a ground in one of the circuits. Should it continue to vibrate when all of the buttons of the combination switch have been pushed in, the ground will almost invariably be found in the horn or its connections. In case no ground can be found in any of the circuits with the aid of the testing lamp, and the circuit-breaker still continues to vibrate, connect the portable testing ammeter in the circuit, using the 30-ampere shunt. Then hold the circuit-breaker closed and note the ammeter reading when it opens. This must be done quickly as the current necessary to keep it operating is small so that the ammeter reading will quickly drop to a value of 3 to 5 amperes. However, the circuit-breaker should

not open on a current of less than 25 amperes. If the ammeter reading indicates that it does so, increase the tension of the spring until the current necessary to operate it shows that it is properly adjusted. In case the instrument shows that the circuit-breaker is opening at the proper point but still continues to vibrate, another series of tests for a ground must be made as the latter is the cause of the trouble.

Seating the Brushes. To insure proper operation of the machine either as a generator or as a motor, it is necessary that the brushes fit the commutator exactly and that they make good contact over their entire surface. If they do not, sparking will occur and the commutator will become burned and blackened, cutting down the efficiency of the machine. The brushes are the only wearing parts of a direct-current generator or motor, and, as this wear on them is constant, they will require attention at intervals to keep them in good condition. Whenever sufficient wear has taken place to make the contact uneven, the brushes must be fitted to the commutator or *sanded-in*. Cut a sheet of No. 00 sandpaper in strips slightly wider than the brush. Emery cloth must *never* be used for this purpose. It is metallic and will tend to cause short-circuits in the commutator. The strip of sandpaper is wrapped around the commutator so as to make contact with at least half of its circumference in the manner illustrated in (*a*) and (*c*) of Fig. 261. The smooth side of the paper is laid on the commutator so that the sanded side rubs the brush. By drawing the sandpaper back and forth, it is possible to fit the brush very accurately to the commutator. It will be obvious that if the sandpaper be applied to the commutator, as shown in (*b*) and (*d*) of the same illustration, that the brush will only touch at its center and there will be excessive sparking between the gaps thus formed.

A high squeaking note caused by the operation of either the generator or motor is an indication that either the brushes or the commutator need sanding-in as the latter will become roughened from the wear. It should be smoothed up by taking strips of the same grade of sandpaper sufficiently wide to cover the commutator, applying them by wrapping in the same manner but with the sanded surface on the commutator bars. This can be done most effectively by running the machine through its other commutator

for a few moments while holding the sandpaper strip in place on the first. If, after this smoothing up, the mica insulation between the bars of the commutator is flush with the surface of the copper bars, it must be undercut as directed in the following section. On most of the Delco machines it will be found possible to sand-in the upper

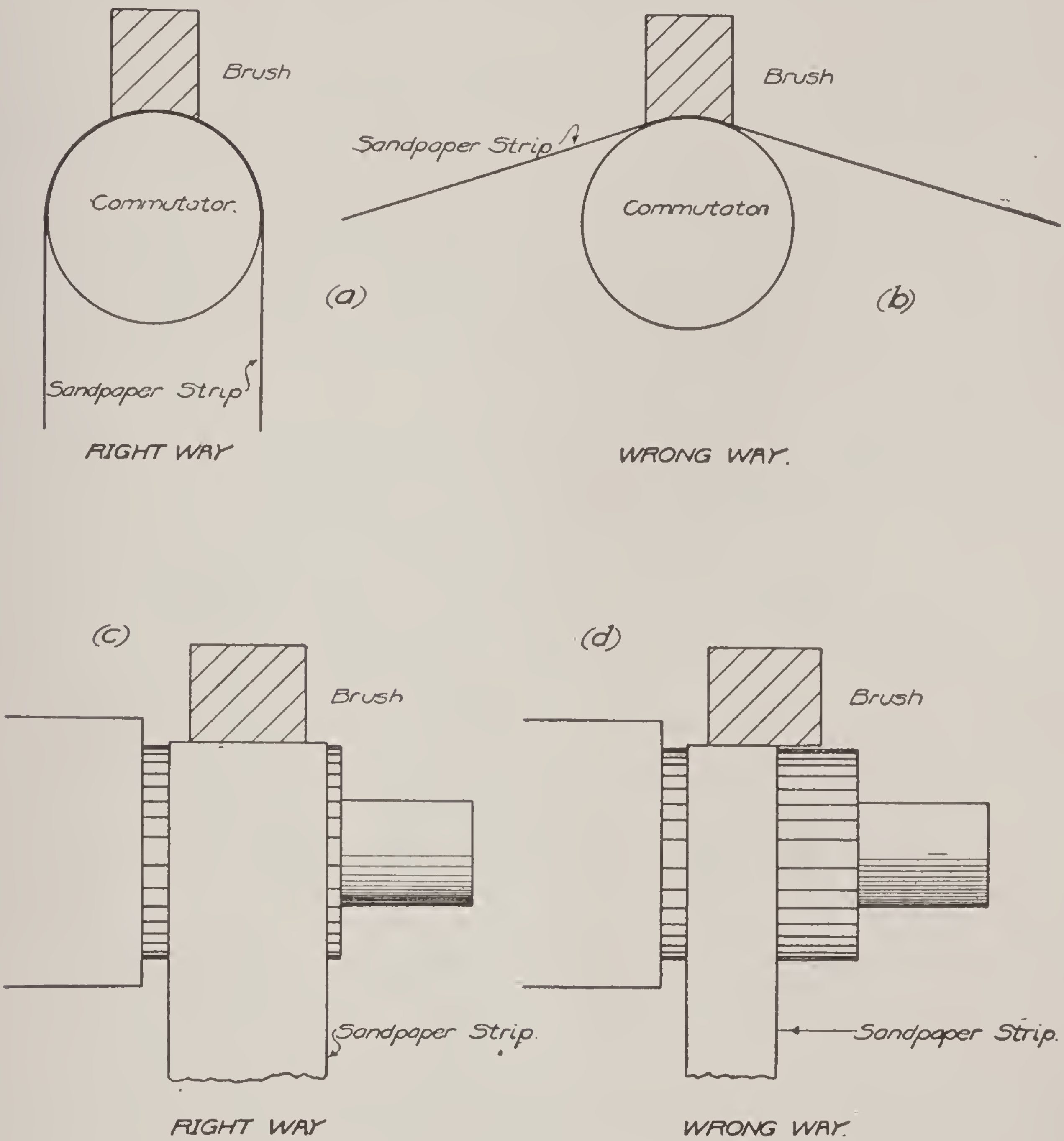


Fig. 261. Method of Sanding-In Brushes

and lower brushes separately by this method, but in a number of cases on account of the construction of the machine, it will be found advisable to sand-in both motor brushes, as well as both generator brushes at the same time. It is unnecessary to lubricate either the motor, the generator brushes, or the commutators, as this simply results in gumming them and causes grit and dirt to collect on the commutator and cut grooves in both it and the brushes.

Commutator Maintenance. In the course of time, the commutator bars of the generator will wear down until they are flush with the mica insulation separating them. When this occurs there will be excessive arcing at the brushes which, in turn, will cause the copper to be burned away until it is level with, or below, the surface of the mica. This condition will be indicated by a rusty black color on the commutator bars. To prevent this condition progressing too far, the commutator should be inspected at intervals and cleaned occasionally with sandpaper as directed. Should this cleaning show that the mica is *high,* it should be undercut as follows:

The armature is removed from the machine and placed in a lathe, truing up both commutators until they are perfectly concentric. This should be done carefully and then as fine a cut as possible taken to avoid wasting the copper

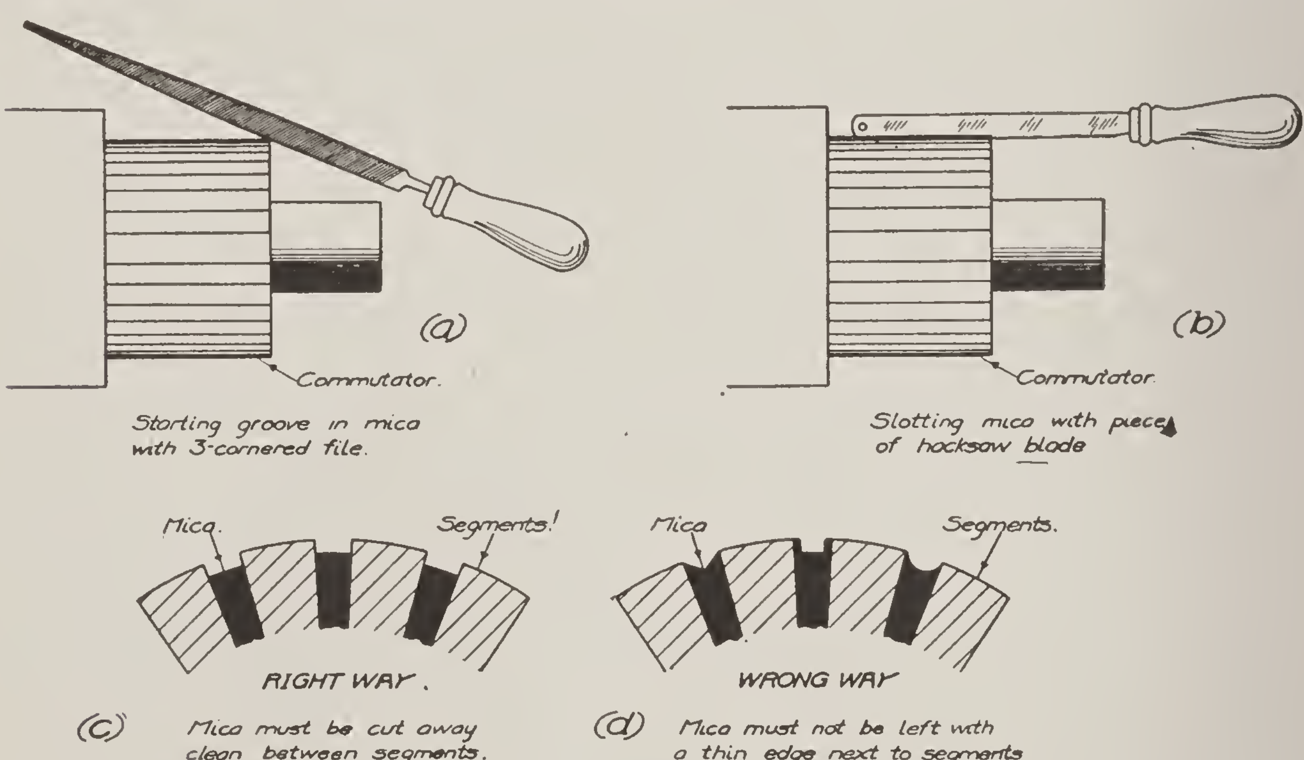


Fig. 262. Method of Undercutting Mica Insulation on Commutator

needlessly. When the commutators have been trued up in the lathe, cut out mica between the commutator bars of the generator only. For this purpose a piece of hacksaw blade should be fixed in a handle, as shown in Fig. 262, and its teeth ground off until they will cut a slot that is just slightly wider than the mica insulation. The cut need not be more than $\frac{1}{32}$ inch deep. In this way a rectangular slot, free from mica, will be obtained between each two adjacent commutator bars. After undercutting the mica, the edges of these slots should be beveled very slightly with a three-cornered file in order to remove any burrs which would cause excessive wear of the brushes.

It is unnecessary to undercut the mica on the motor commutator, as, wherever metal or metallic brushes are used on Delco machines, they are sufficiently hard to keep the mica flush with the surface of the copper as it wears down without any undue arcing at the brushes, whereas in the case of generators provided with

carbon brushes, the carbon is not hard enough to do this. After completing the undercutting, the commutator when viewed from the end should show clean-cut rectangular slots between the bars, as in the left-hand view, Fig. 262. The machine should then be reassembled and the brushes sanded-in to the commutator, as previously described. This operation of fitting the brushes to the commutator will be necessary whenever anything has been done to the commutator, when new brushes are installed, or when the third-brush location is readjusted to vary the output of the machine on generators having this type of regulation.

These instructions for fitting the brushes, cleaning the commutator, and undercutting the mica of the commutator of any machine equipped with soft-carbon brushes, apply with equal force to all makes of generators and starting motors employed on automobiles. Next to the battery the brushes and commutators will be found to demand most attention—or to put it another way, they will be found to constitute a cause of trouble only second in importance to the battery. It must not be assumed, however, that all blackening of the commutator is caused always by high mica. Any one of the following conditions may cause the commutator to assume an appearance similar to that produced by high mica: (1) generator brushes of improper size or material, as where replacements other than those supplied by the manufacturer of the machine have been installed; (2) insufficient spring tension on brushes—all springs slacken up in time and they should be examined at intervals to see that the brushes are being held firmly against the commutator; (3) overloading of the generator caused by partial failure of the regulating device or other cause; and (4) an open- or short-circuit in the generator windings, or a short-circuit between generator and motor windings in a single-unit machine like the Delco.

Testing Armatures. In reading the foregoing instructions as well as those that follow here concerning the Delco system, it should be borne in mind that they apply in principle, and in many cases in actual detail, to the majority of other systems described. In other words, all starting and lighting systems are based on the same principles and, while many of them differ in detail and in design, the application of the instructions in question will very frequently be evident by comparing them point for point and modifying the instructions to compensate for any slight differences in design or wiring.

Armature troubles are of much less frequent occurrence than the majority of defections, such as worn brushes, dirty commutator, or

the like, which temporarily put the system out of commission, so that every part of the system which might be at fault should be investigated before attempting to test the armature for faults. To carry out these tests, the voltmeter and the lamp-testing set are necessary. Where no previous experience has been had in making tests with these aids, it will be well to become familiar with the detailed instructions given for their use in connection with the determination of other faults, as already described. It is not necessary to remove the dynamotor from the car for this purpose. When tests of the remainder of the system indicate no faults and when grounds in the armature windings or short-circuits between them are not suspected, raise all the brushes from the commutator and slip pieces of cardboard between the brushes and the commutator so as to insulate them from each other. These instructions cover the single-unit Delco machine, so the foregoing applies as well to testing for short-circuits between generator and motor armature windings. For greater simplicity, the possible faults and the tests for locating them are treated under different heads, as follows:

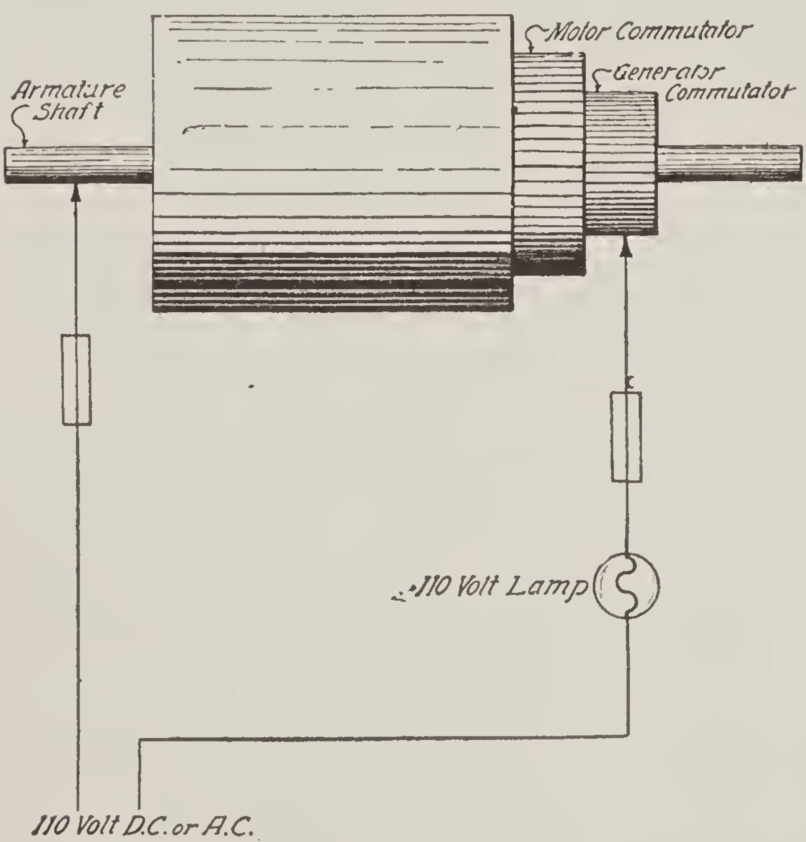


Fig. 263. Diagram for Locating Grounded Generator Coil with Lamp-Testing Set

(a) *Grounded Generator Coil.* On one-wire systems of the single-unit type, the presence of a grounded generator coil will materially reduce the charging rate to the battery and will also result in slow cranking of the engine. To determine whether a generator coil has become grounded, place one of the test points on the frame or on the armature shaft, both of which are grounded, and the other on the generator commutator, as shown in Fig. 263. If the lamp lights, it indicates a ground on the commutator. The test of the generator of a two-unit set would be carried out in exactly the same manner.

(b) *Grounded Motor Coil.* According to the nature of the fault, a grounded motor coil may either prevent operation of the starting motor altogether or it may result only in an excessive consumption of current for starting. The test is carried out in the same manner as described for the generator, except that the second point of the test set is placed on the motor commutator, Fig. 264. It will likewise be evident that an independent starting motor can be tested in the same way.

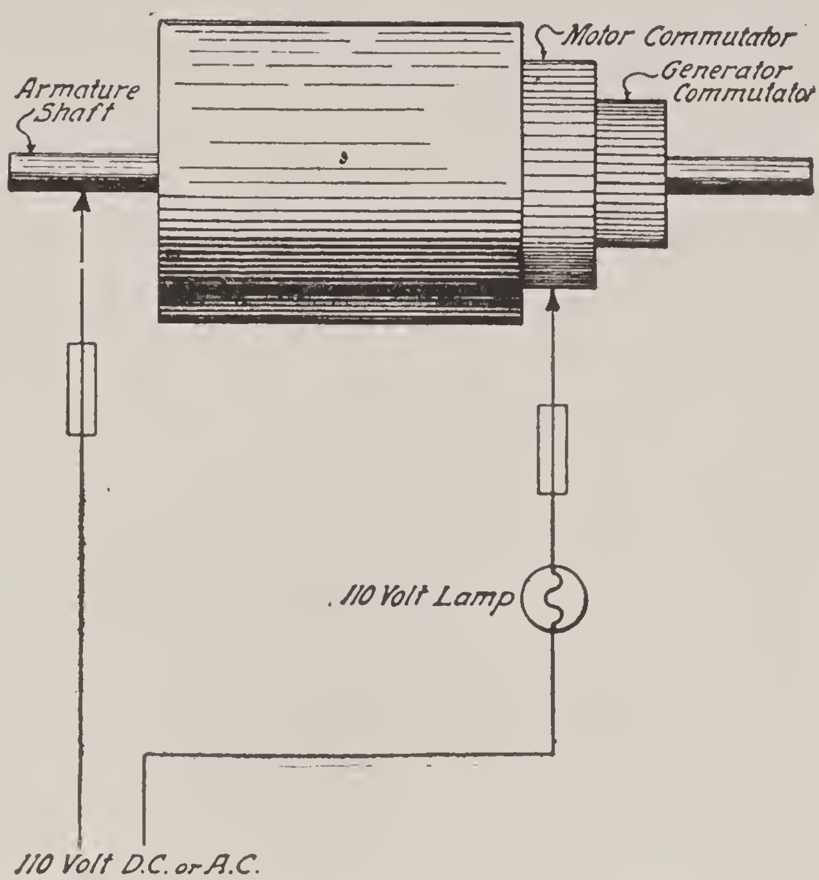


Fig. 264. Diagram for Locating Grounded Motor Coil with Lamp-Testing Set

(c) *Short-Circuits between Motor and Generator Armature Coils.* In most cases short-circuits between motor and generrator armature coils will decrease the speed of cranking and will cause the armature to continue to run after the engine has been shut down. This test is carried out by simply placing one test point on the generator commutator and the other on the motor commutator. If the lamp lights, it indicates a short-circuit between the generator and motor windings, Fig. 265. This test is

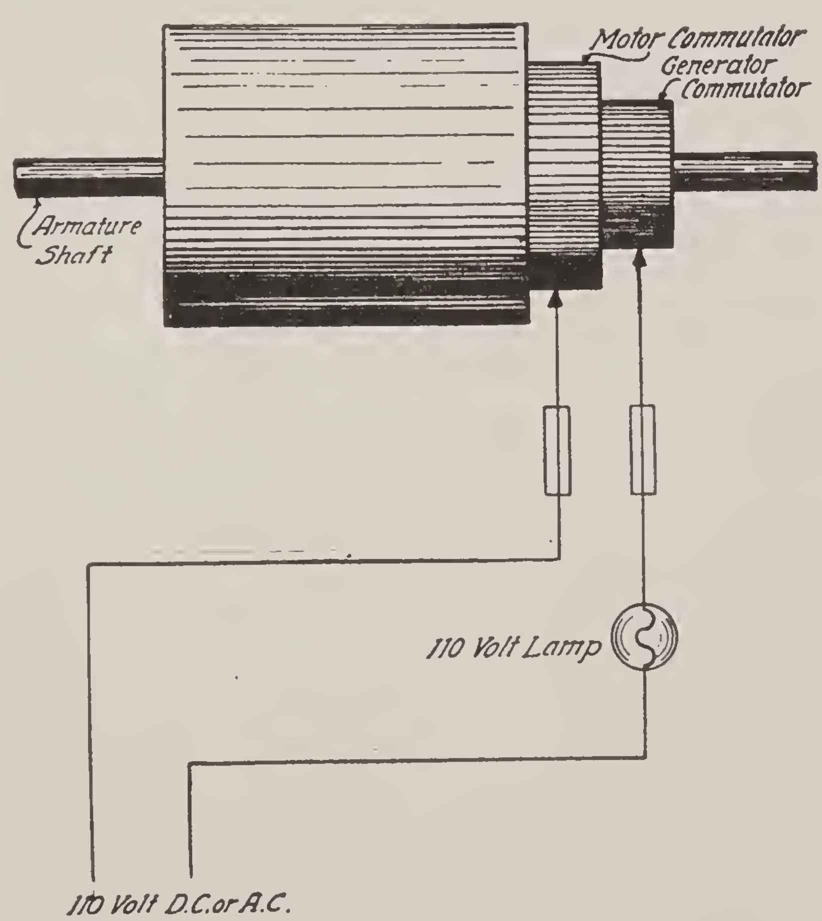


Fig. 265. Diagram for Locating Short-Circuits between Motor and Generator Armature Coils

naturally only applicable to single-unit machines having two independent windings on the same armature core, as in the case of the Delco, the type in question.

(d) *Open- or Short-Circuited Generator Armature Coils.* When testing for open- or short-circuited generator armature coils, the generator brushes should be left in contact with the commutator, but the storage battery should be disconnected from the system, carefully taping the loose battery terminals before proceeding. Then disconnect the shunt field from the brushes and tape these terminals so that they do not accidentally come in contact with the frame or other parts

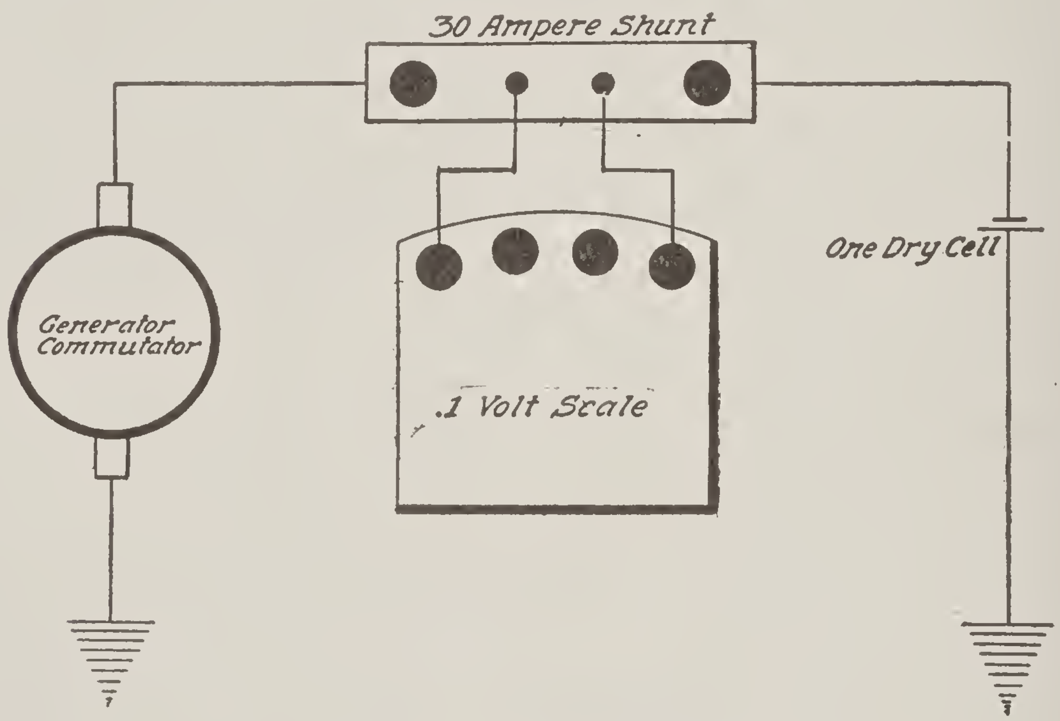


Fig. 266. Diagram for Testing Open- or Short-Circuited Generator Armature Coil with Ammeter

of the unit. Connect up a dry cell and the portable ammeter, using the 30-ampere shunt, as shown in Fig. 266. Turn the armature over slowly by hand. If the commutator is clean and bright and the brushes are making good contact with it, a very noticeable change in the ammeter reading will indicate an open- or a short-circuited armature coil. To determine whether the coil is open- or short-circuited, the following tests should be made:

(1) *Open-Circuited Coils.* Connect the brushes to the terminals of the dry cell so that a current of about 10 amperes is flowing through the brushes. The field should be entirely disconnected and its terminals either taped or held out of the way. Then, with a special pair of points connected to the voltmeter,

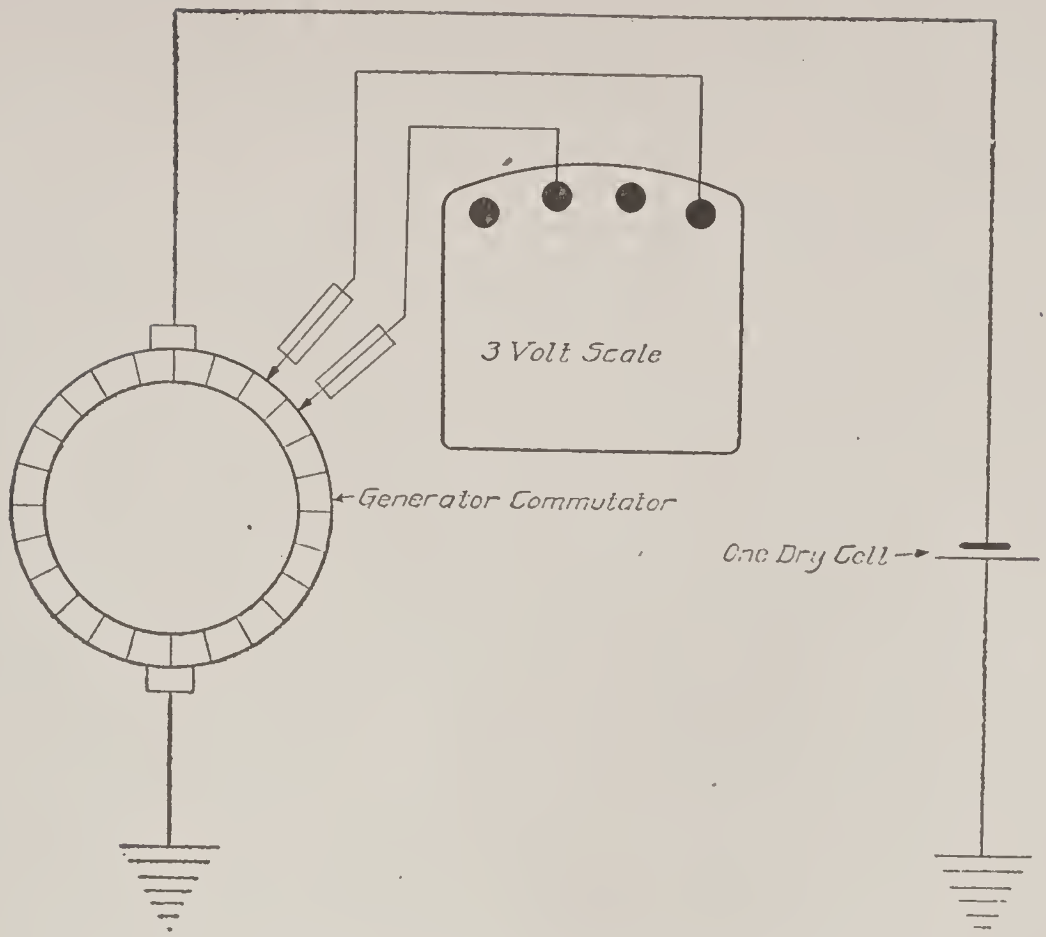


Fig. 267. Diagram of Set-Up when Coils Are Open-Circuited

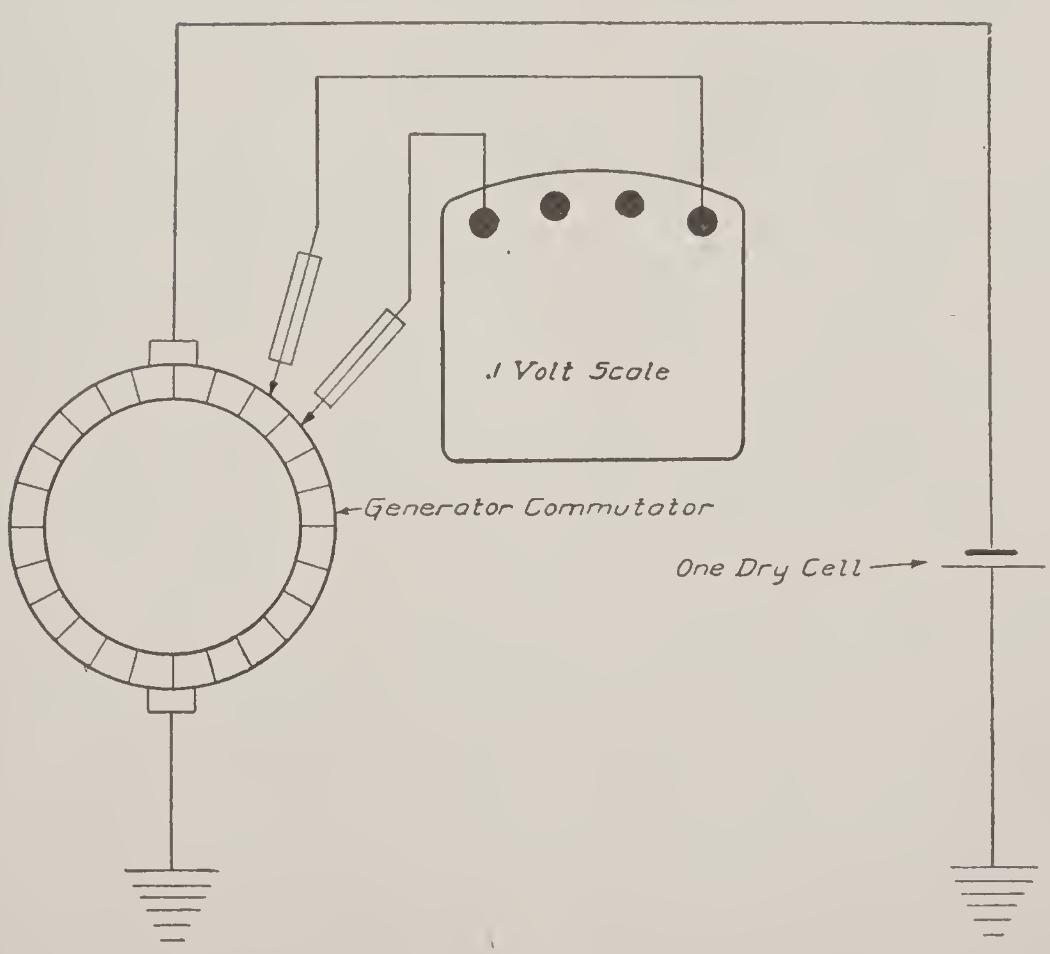


Fig. 268. Diagram of Set-Up when Coils Are Short-Circuited

using the 3-volt scale, measure the voltage across each two adjacent commutator bars. If there is an open-circuited coil in the armature, the voltage reading will increase considerably, Fig. 267.

(2) *Short-Circuited Coils.* If there are no open-circuited coils and the preceding tests indicate that there is trouble with the armature, it should be tested for short-circuited coils. This should be done only after the preceding tests have been made, as an open-circuited coil might cause the .1-volt scale of the voltmeter to burn out if this test were made first. The armature is connected as indicated in(1) above, but for this test the .1 -volt scale instead of the 3-volt scale of the voltmeter is used, Fig. 268. The voltage drop between adjacent commutator bars is then measured by slowly turning the commutator over by hand. The readings should be approximately the same. If any of them drop nearly to zero, it will indicate that one or more of the armature coils are short-circuited. In taking these readings, care must be observed to keep the points always on adjacent commutator bars and not allow them both to come on the same bar at any time; otherwise, the voltage drop may be sufficient to injure the voltmeter.

Should any of these tests indicate open- or short-circuited coils in the armature, it is advisable to send the armature to the manufacturer for repairs, or to install a new armature. Unless the fault is plainly visible, as where a coil-terminal connection at the commutator bar has broken or become short-circuited, the average establishment will find the repair entirely beyond its facilities to make, so that time and expense will be saved by promptly referring it to the factory. Special equipment and skill in the handling of such repairs are indispensable and are beyond the province of the garage man.

Testing Field Coils. The tests of field coils are simpler than those of the armature, and they apply in large measure to practically any system.

Open-Circuits in Fields. To test for open-circuits in fields, the test set is the only apparatus required, and the points should be placed as shown in Fig. 269. By placing one point on each terminal of the particular winding to be tested, failure of the lamp to light

will indicate that the coil is open-circuited, as the wire of the coil will afford a path for the current, unless broken. The fact that the lamp may not light to full brilliance in some of these coil tests is no indication of trouble, as the difference is simply due to the additional resistance represented by the coil itself. In case an open-circuited coil is found, the only remedy is to return it to the manufacturer for repair or replacement.

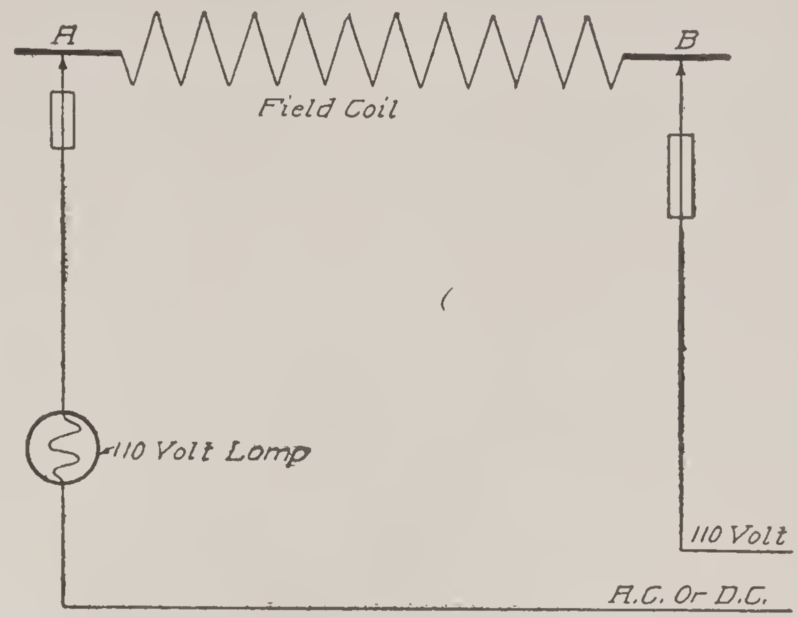


Fig. 269. Diagram for Locating Open Circuits in Field Coils with Lamp-Testing Set

Grounded Fields. To test for grounds in the field windings, place one test point on the frame of the machine and the other on a terminal of the field coil. Before doing this, however, all intentional ground connections made by the terminals should be removed. These can be located by referring to the winding diagram. If the lamp lights, it will indicate a ground. The manner of applying the test points is shown in Fig. 270.

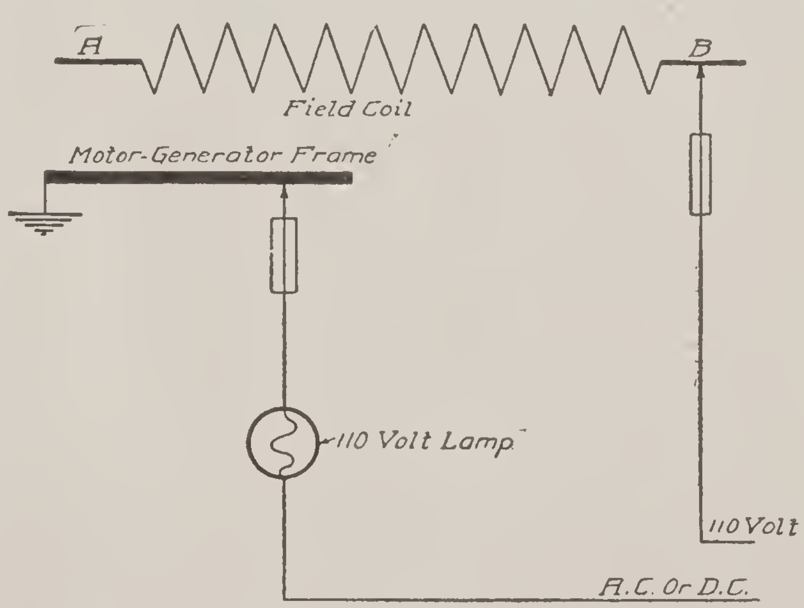


Fig. 270. Diagram for Locating Grounded Fields

Short-Circuits between Windings. To test for short-circuits between windings not normally connected, as for example the shunt and series winding of a field coil, place one test point on the terminal of one winding and the other test point on the terminal of the other field winding, as shown in Fig. 271. If the lamp lights, it will indicate a short-circuit between the windings. The field coils can also be tested with a voltmeter, the 30-volt scale being used in connection with a 6-volt storage battery for this purpose, Fig. 272. Detailed instructions for the use of the instrument are given in a previous section. As

all lighting generators have more than one winding on their fields, i.e., shunt and series windings (the latter termed "bucking coils" when reversed), these tests are equally applicable to all makes.

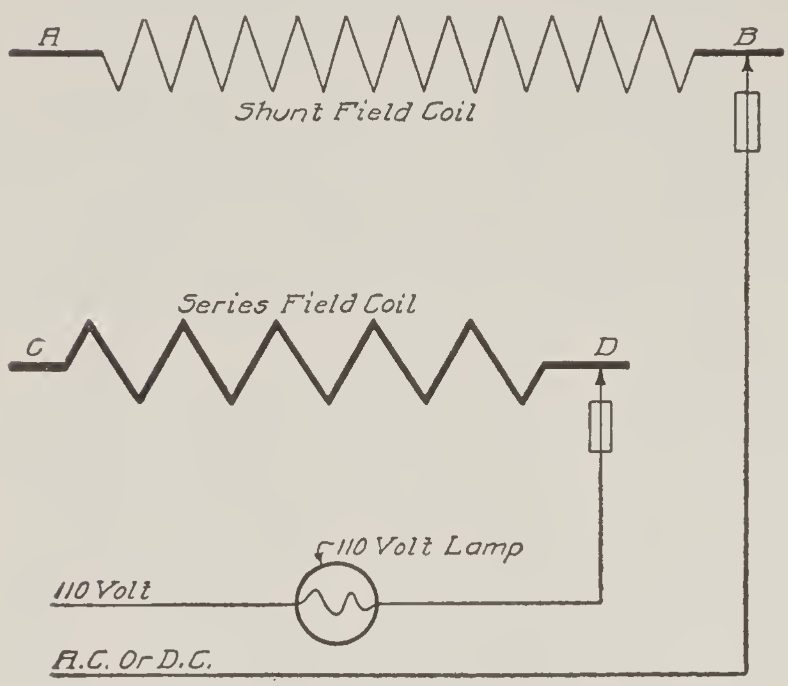


Fig. 271. Diagram for Testing Short-Circuits between Windings

Voltmeter Field Tests. The method of employing the voltmeter for making field tests, shown in Figs. 272 and 273, is as follows:

To test for an open-circuited field, connect up as shown in Fig. 272. The positive terminal of the voltmeter is connected to the positive terminal of the battery. An insulated copper wire of convenient length, with the insulation stripped off for about one inch at each end, is then attached to the terminal of the voltmeter marked "30 volts", and a similar wire is attached to the negative terminal of the battery. The free ends of these wires are then used in the same manner as the points of the test set, except that the voltmeter reading is the indication sought instead of the lighting of a lamp. Before making the test, touch the free ends of the wires together. This reading will be the total voltage of the storage battery, and it should be kept in mind when making the tests.

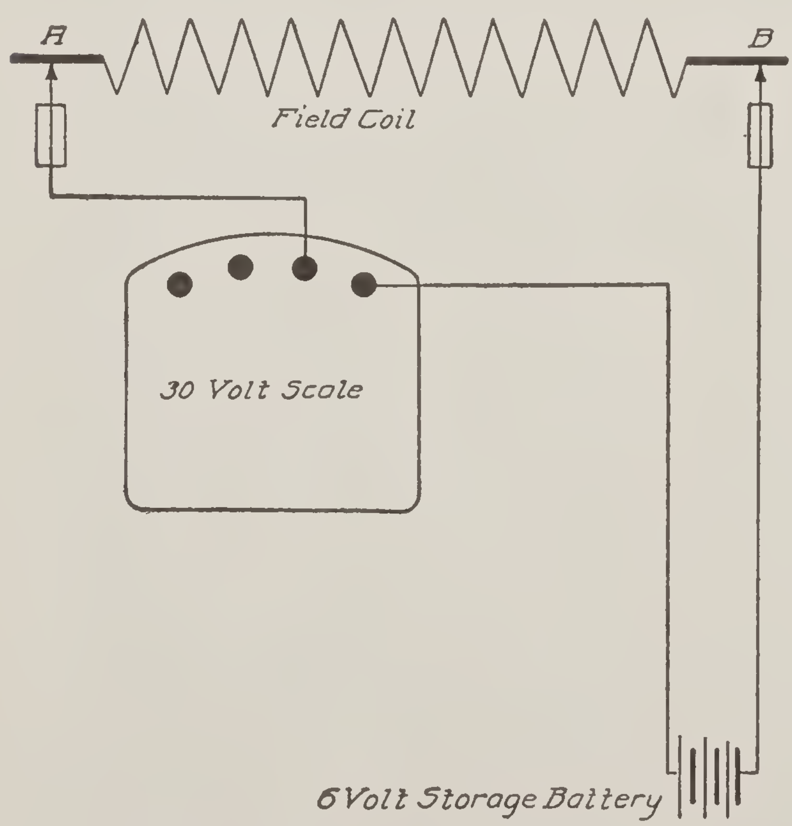


Fig. 272. Voltmeter Test Diagram for Open-Circuited Field

If, instead of touching the free ends of the wire together, they are placed on the terminals of a high resistance, the voltmeter reading will

naturally be much less. In other words, the value of the voltmeter reading will always depend upon the amount of resistance offered by the coil or other circuit that is being tested. When there is no circuit, as with the free ends held apart in the hands, there will be no indication on the voltmeter scale. An open-circuited coil will accordingly be indicated by a zero reading of the voltmeter when the two free ends, or points, are placed upon the terminals of the coil, Fig. 272. If, on the other hand, the voltmeter reading is nearly half of that of the battery voltage, the coil is in good condition. This test corresponds to that with the lamp-testing set using the 110-volt

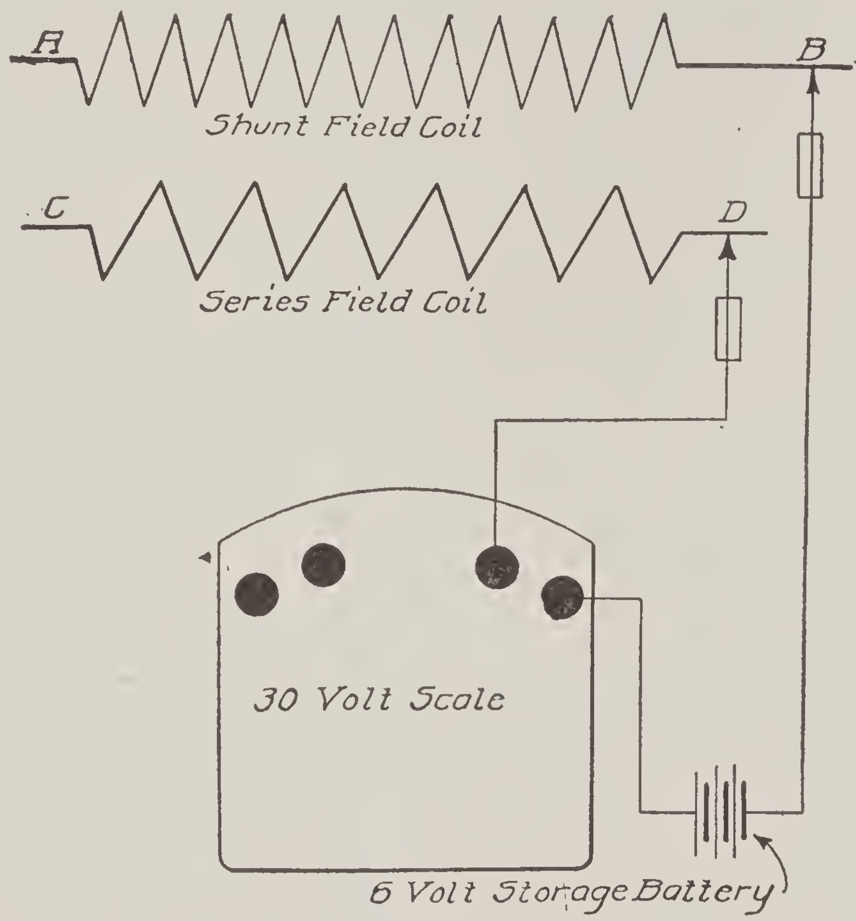


Fig. 273. Voltmeter Test Diagram for Short-Circuit between Coils

current, illustrated in Fig. 269. It is a method which also permits one coil to be checked against another of the same kind, as the readings given by the two coils should be approximately the same. Where neither a 110-volt current nor a portable voltmeter are available, these tests may be carried out with the aid of a 6-volt bulb in connection with the storage battery, as shown for the voltmeter tests. In this case, the lamp will light brightly when the free ends of the wires are brought together, but it will dim in proportion to the amount of extra resistance added to the circuit, as represented by the coil under test. While not so accurate as the tests with the voltmeter, comparative

tests are also possible with the low-voltage lamp, a very perceptible difference in the lighting of the lamp indicating a greatly increased resistance. When using current from a storage battery for testing, care must be taken to have the points of the test set, or ends of the wire, clean and bright, and to make good, firm contact. If necessary, places on the machine at which the test points are to be applied should first be scraped or filed clean, otherwise, additional resistance will be inserted by the poor contact at the points, as for example, where the latter are applied to a painted surface.

To test for grounds in a field, after having removed all ground connections, as mentioned in a previous paragraph, place one end, or point, on a terminal of the field coil and the other on the frame of the machine. The method of making the test is identical with that shown in Fig. 270, except for the substitution of the voltmeter for the 110-volt light circuit. If the coil is free from grounds, the voltmeter needle will remain at zero; in case, there is a ground, there will be an indication on the instrument and the worse the ground the greater the value of this reading will be. This test corresponds to that illustrated in Fig. 264.

Short-Circuits between Coils. The test for short-circuits between coils is similar to that shown in Fig. 265 and naturally applies to all lighting generators where the two windings of the fields are concerned. Place one end, or point, on the terminal of one winding and the other end on the terminal of the other winding, as shown in Fig. 273. If there is no connection between the coils, as should be the case, the voltmeter needle will remain stationary. Any movement of the voltmeter needle indicates a short-circuit and the greater the value of the reading, the more complete is the short-circuit between the two coils.

In order to make these tests without removing the machine from the car, first, disconnect the storage battery and tape the disconnected terminals; then, insulate all the brushes by placing pieces of cardboard between them and the commutators. Disconnect all wires leading to generator terminals, and, likewise, all wires leading to field-coil terminals. By referring to the circuit and wiring diagrams for the particular car under consideration, all these leads can readily be identified, and after disconnecting them, the field coils of the machine can be tested. When the tests indicate that the field coils

are not in perfect condition, it will usually be found advisable to remove the field coils from the machine and send them to the manufacturer for repair or replacement, for unless the fault is plainly apparent, which will seldom be the case, the repair will usually be found to be beyond the average garage facilities.

DISCO SYSTEM

Twelve-Volt; Single-Unit

Dynamotor. The dynamotor is bipolar with both windings connected to the same commutator.

Regulation. Constant current-control regulation by means of a vibrating regulator is employed. (See description of the Ward-Leonard regulator, Fig. 149, Part IV.)

Operating Devices. *Battery Cut-Out.* The cut-out is of the conventional type, combined with the current-control regulator.

Switch. The switch is the spring-controlled type which is only closed for starting.

Six-Volt; Two-Unit

Units. Both the generator and the starting motor are of the bipolar type, the motor being designed to operate through a Bendix drive.

Instructions. As both types of the system are characterized by standard features throughout, instructions given in connection with other systems apply here.

DYNETO SYSTEM

Twelve-Volt; Single-Unit; Single-Wire

Dynamotor. *Non-Stalling Feature.* Both windings are connected to the same commutator. No battery cut-out is employed, control being by means of a single-pole knife-blade switch, which is closed for starting and left closed as long as the engine is running. This switch also controls the ignition circuit. Upon closing the switch, the dynamotor acts as a starter and turns the engine over; as soon as the engine takes up its cycle and drives the dynamotor above a certain speed, the latter automatically assumes its functions as a generator and begins to charge the battery. Whenever the speed drops below that point, the dynamotor again acts as a motor

to turn the engine over, this characteristic being termed the "non-stalling" feature of the system. Provided the battery is sufficiently charged, the dynamotor will always act as a starter (the switch being closed) whenever the engine is inadvertently stalled or its speed drops below the generating point of the machine.

Instructions. The switch must never be left closed with the engine stopped, and when the car is stopped, the engine must not be allowed to idle at a very low speed, as in either case the battery will be run down. Instructions for lack of generator capacity the location of grounds or short-circuits, and the like, are the same as for other systems.

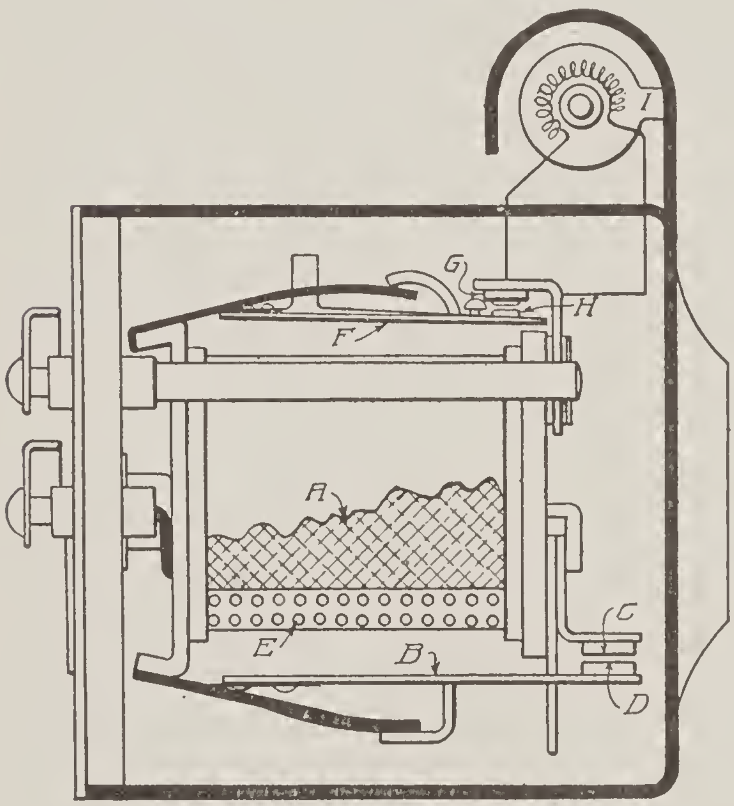


Fig. 274. Sectional View Showing Details of Dyneto Regulator-Cut-Out

Six-Volt; Two-Unit

Generator. The generator is a standard shunt-wound machine of the four-pole type, having two wound, or salient poles, and two consequent poles. (See Fig. 219, Part IV.) It is ordinarily designed to be driven at one and one-half times engine speed, but, in common with other makes, machines wound for higher or lower speeds are furnished, according to the requirements of the engine on which it is mounted.

Regulation. Regulation is effected by means of a vibrating regulator, which is combined with the battery cut-out. This cuts in at a speed equivalent to 10 miles per hour, and the generator reaches its maximum normal output of 10 to 12 amperes between 12 and 15 miles per hour. The regulator does not become operative until the current flow increases to 10 to 12 amperes, at which point it is held regardless of the speed. The details of the combined regulator and cut-out are shown in Fig. 274, while all the connections are shown in the diagram, Fig. 275. As soon as the dynamo runs fast enough to cause it to generate, a portion of the current passes through the

winding *A* of the cut-out, Fig. 274. This is ordinarily known as the voltage winding and is of fine wire, so that very little current is required to energize the core and attract the armature *B*, which closes the contact points *C* and *D*. These points close the circuit through the coil *E*, which is of heavy wire and is known as the current coil. As the current in both coils is in the same direction, their exciting effect on the magnet core is cumulative, and the points are held together that much more firmly.

On the upper side of the magnet will be noted another armature *F* and a set of contact points *G* and *H*. This armature is subject to the same magnetic attraction, but the tension of its controlling spring is

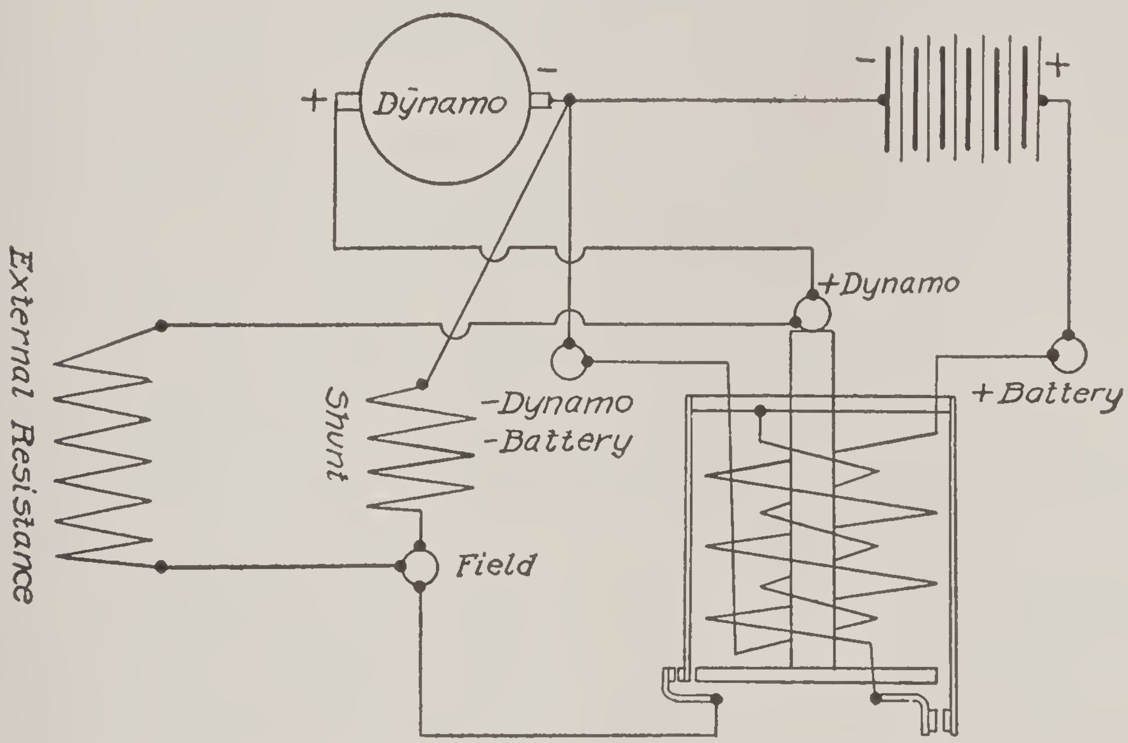


Fig. 275. Connections for Dyneto Regulator Cut-Out

such that the magnet is not strong enough to move it. This spring is so adjusted that any increase in the current beyond this point will cause armature *F* to be attracted, opening points *G* and *H*. These points are directly in the shunt-field circuit and a resistance coil *I* is connected across them, so that when the points are together, the resistance is cut out of the shunt-field circuit; when they separate, this resistance is added to that of the shunt field. With a charging rate of 10 to 12 amperes, the tendency toward any higher output with increased speed is checked by the almost imperceptible but very rapid vibration of the armature *F*, which cuts the resistance unit in and out of the circuit and causes a pulsating current to be sent through the

field windings, thus keeping the output within the required limits. When the generator speed falls below the normal rate, the voltage drops correspondingly and the battery current overcomes that from the generator and reverses the current flow through the current coil *E*. This reverses the magnetic effect produced, *bucking* that caused by the generator current in the coil *A*, and, as the battery current is then superior to the latter, the magnetic effect of *A* is neutralized and the armature *B* is forced away, opening the contacts *C* and *D*.

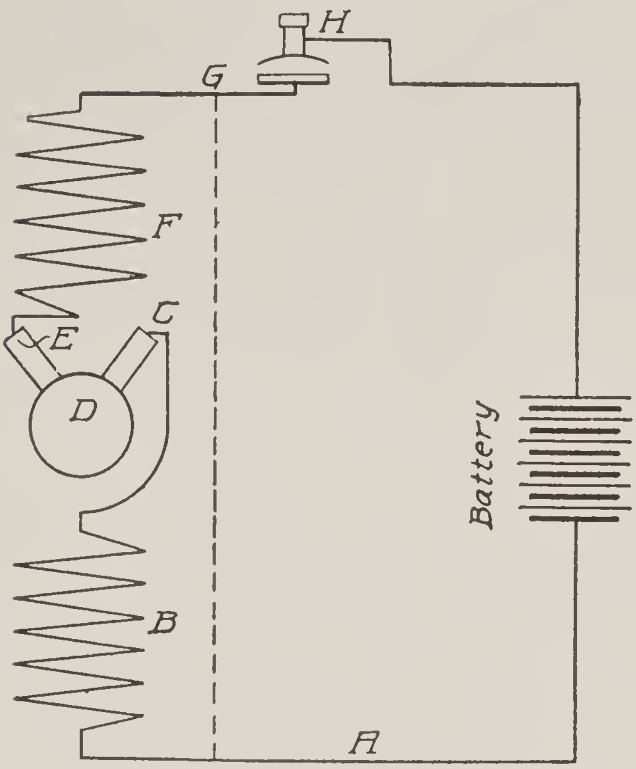


Fig. 276. Starting-Motor Circuit for Dyneto System

Starting Motor. This starting motor is of the standard series-wound type of the same characteristics of design as the generator. In Fig. 276 is shown the wiring diagram of the starting circuit and illustrates plainly the relation of the series fields *B* and *E* to the armature *D* and the brushes *E* and *C*. *H* is the starting switch and *A* and *G* are the cables of a two-wire starting system. Compare Fig. 276 with Fig. 277, which shows the shunt windings of the generator and their relation to the armature and battery. In Fig. 276 the dotted line from *G* to *A* illustrates a supposed short-circuit caused by chafing, or abrasion, of the insulation of the wires.

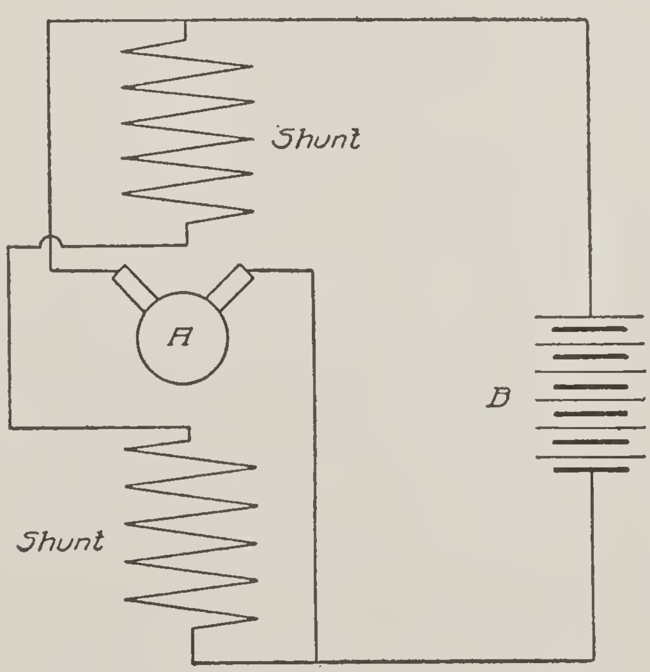


Fig. 277. Generator Circuit for Dyneto System

Wiring Diagrams. Either the single- or the two-wire system of wiring is employed, according to the car on which the system is installed. Fig. 279 shows the one-wire, or grounded, system, and Fig. 279 shows the two-wire system.

Instructions. In case of failure to start, the switch should always be released instantly and the battery tested to determine its condition

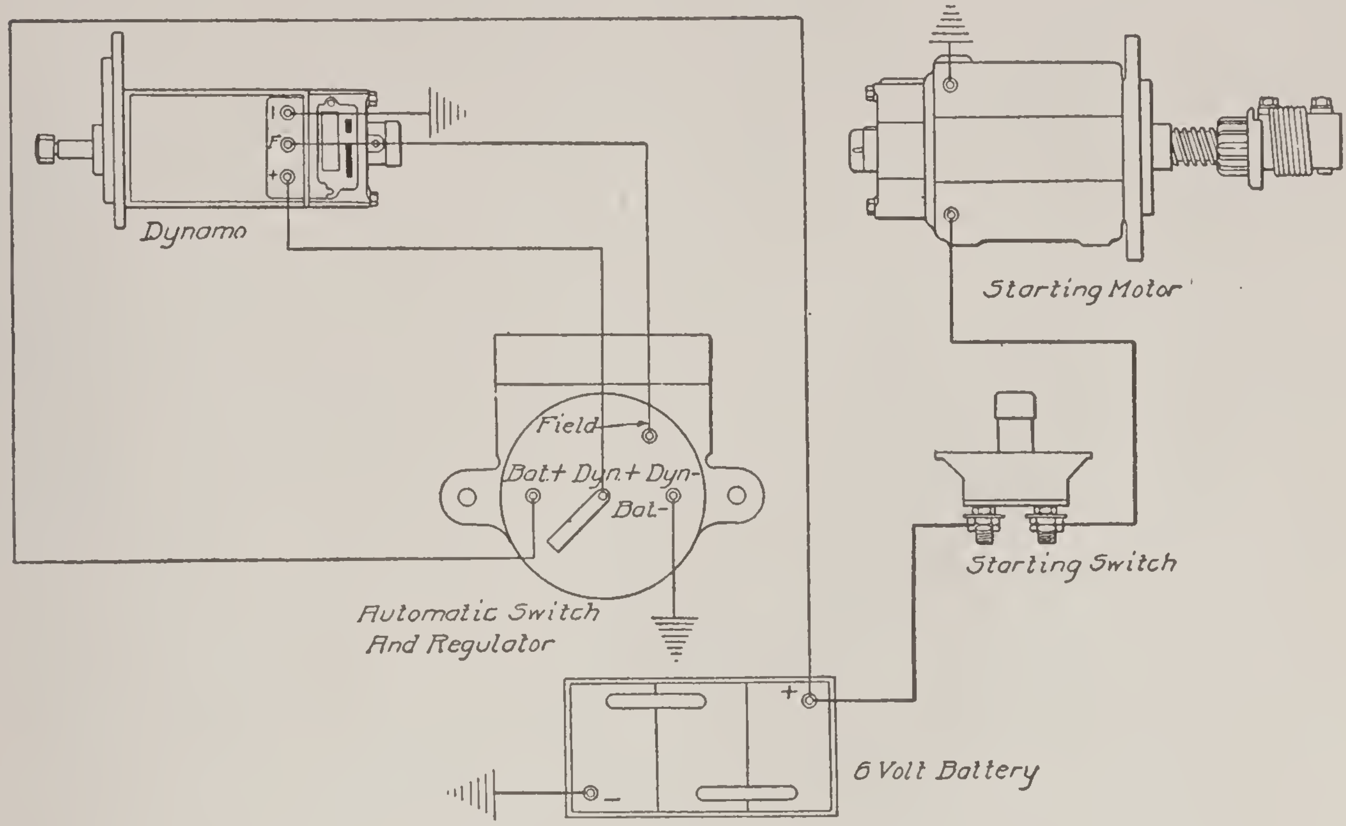


Fig. 278. Wiring Diagram for Dyneto One-Wire System

of charge. If the battery is not run down, examine all connections and wiring, for, if a short-circuit exists as indicated by the dotted line

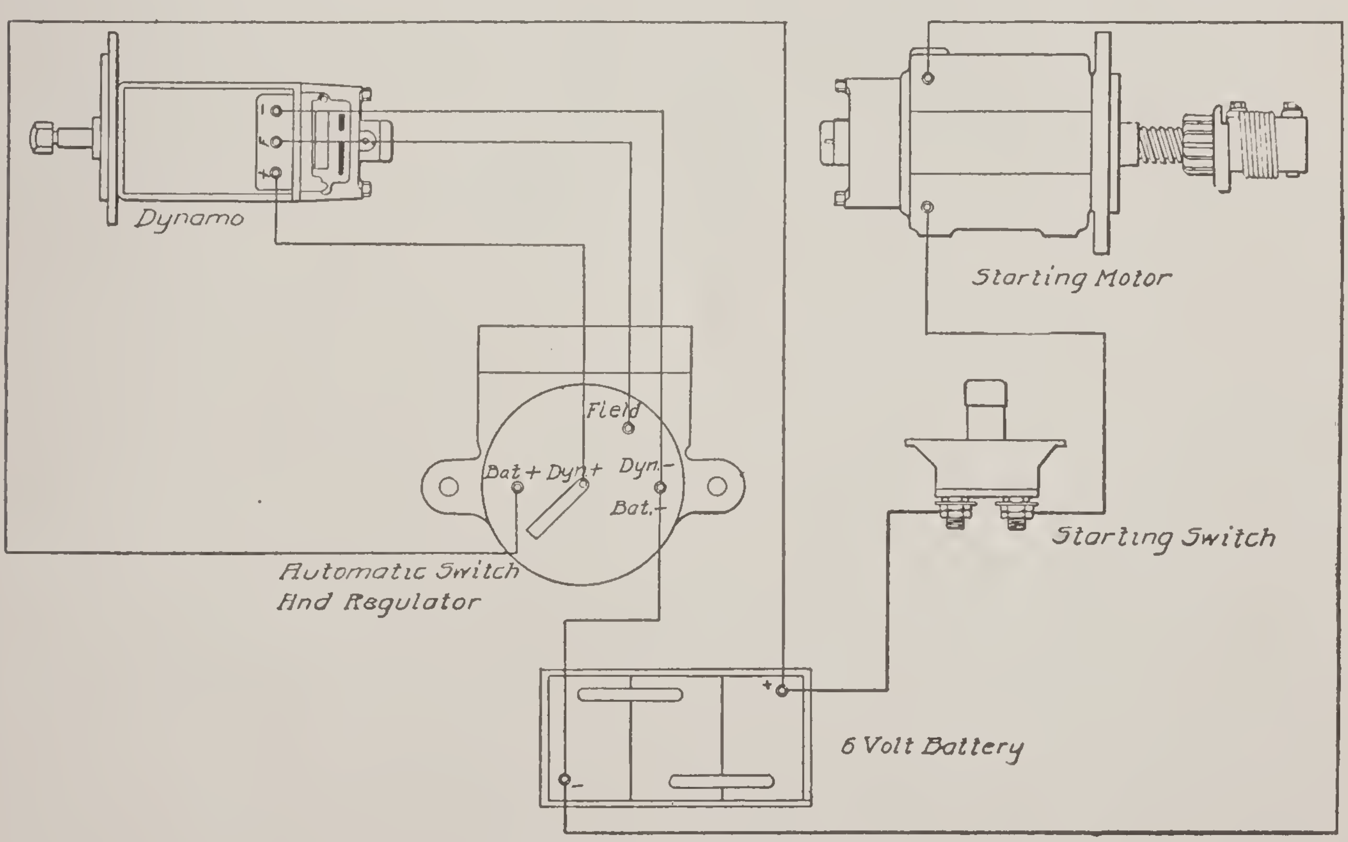


Fig. 279. Wiring Diagram for Dyneto Two-Wire System

at *G* in Fig. 272, no current can reach the motor. Failing to locate any short-circuit or ground in the system, open the name-plate cover

on the starting motor and inspect the brushes. Lift each brush holder a trifle (if they are in proper condition, they should spring back when released) and press the brushes firmly against the commutator. (See Gray & Davis instructions for Spring Pressures on Starting Motors. These pressures are not the same on all makes, but this will give some idea of the high pressure necessary to make the contact required to handle the heavy currents used in the starting motor.) See that the commutator is clean and the brushes are making uniform contact all over their surfaces. Make sure that the two leads from the field coils to the brush holders are screwed down tightly.

When it is necessary to renew the brushes, remove the eight screws shown holding the end plate. Remove this commutator housing, or end plate, leaving the brush unit in place on the commutator. Remove only one brush at a time and replace it with a new one. Note bearing of brushes on commutator and sand-in to a true and uniform bearing over the entire surface of the end of each brush. When this has been done, carefully clean out all traces of carbon dust, using a rag wet with gasoline, if necessary; a small bellows may be used to advantage to blow this dust out dry, and will be more likely to get it out of the nooks and crannies then wiping. After the brushes have been sanded-in and the dust all cleaned out, see that both brush leads are tight and then replace the housing. New brushes should be necessary only after a year or two of service, sometimes longer; old brushes will operate just as efficiently as new ones, provided they have a bearing all over their surface and are held firmly against the commutator. A brush becomes too short for further use only when the spring can no longer hold it in good contact against the commutator. When ordering brushes, it must always be specified whether they are wanted for the generator or for the motor, and the type of machine, as stamped on the name plate, must be given. This applies equally to the brushes needed for any make of generator or starting motor, and no other brushes than those supplied by the maker for the machine in question should ever be used.

GRAY AND DAVIS SYSTEM

Six-Volt; Two-Unit; Single-Wire

Generator. The bipolar generator is designed for drive by silent chain, as shown in Fig. 280, or when combined with ignition distributor from the pump shaft, Fig. 281.

Regulation. Earlier types, including the original lighting generator, were of the constant-speed type regulated by a governor and slipping clutch, which maintained the speed of the generator constant. The 1914 and subsequent models are controlled by a combination regulator cut-out, usually mounted directly on the generator itself. The regulator increases the resistance of the generator-field windings in proportion to the increase in speed, thus maintaining a steady output.

Starting Motor. The series-wound bipolar motor is made for either open or enclosed flywheel drive, according to the type of car. In Fig. 282 is shown the open flywheel type. The illustrations of

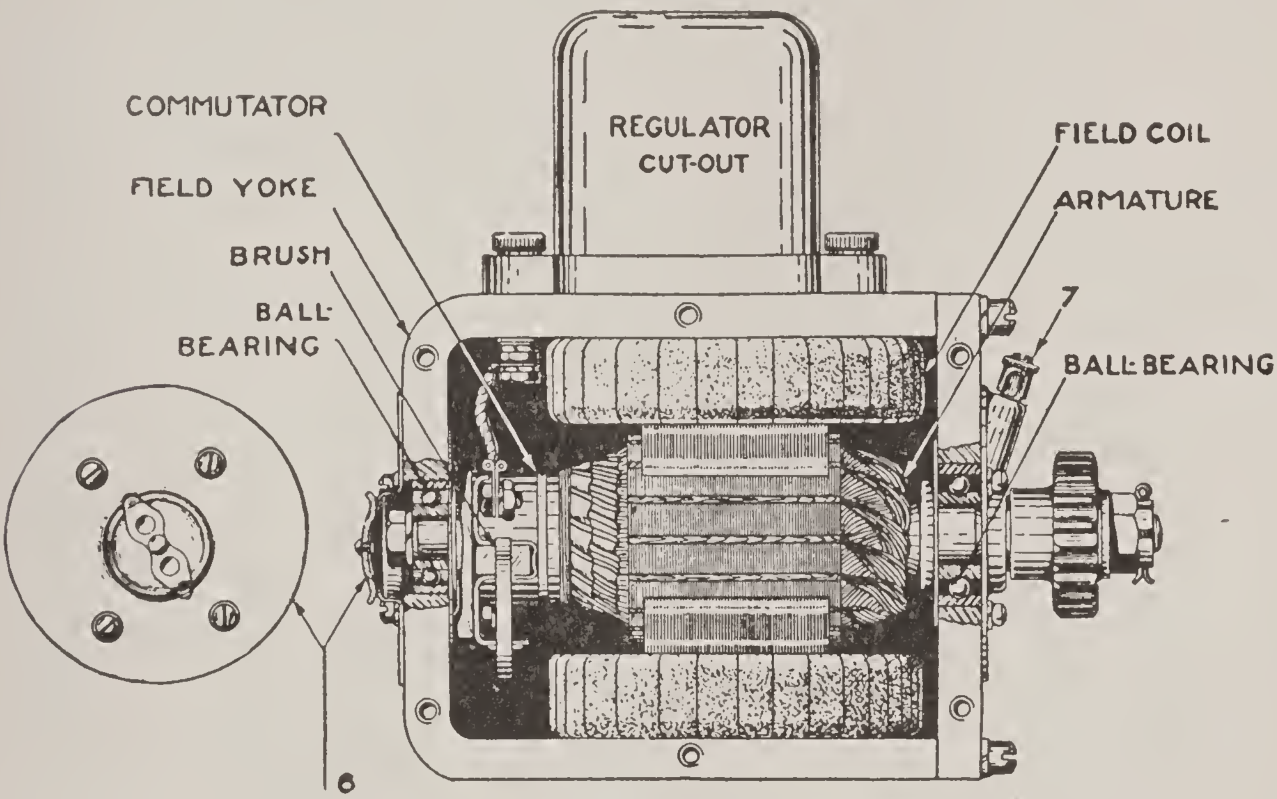


Fig. 280. Section of Gray & Davis Generator for Silent-Chain Drive

both generator and motor show them with the side plate removed for inspection. The type of starting switch employed on later models is shown in Fig. 283. The rod passing through the switch leads to the pedal on the footboards for operating it.

Instruments. Either an indicator showing whether the battery is charging, discharging, or is neutral, or an ammeter serving the same purpose, is supplied. The ammeter is provided with a graduated scale and its normal readings should be as follows: Standing, no lights on, *zero;* with lights on, *discharge* 5 to 7½ amperes. Car running 6 to 8 miles per hour, lights on, *discharge* same rate. Above 8 miles per hour, lights off, *charge* 5 to 9 amperes; above 10 miles

per hour, lights on, *charge* $3\frac{1}{2}$ to amperes. Under the last-named condition, the lights are being supplied directly by the generator

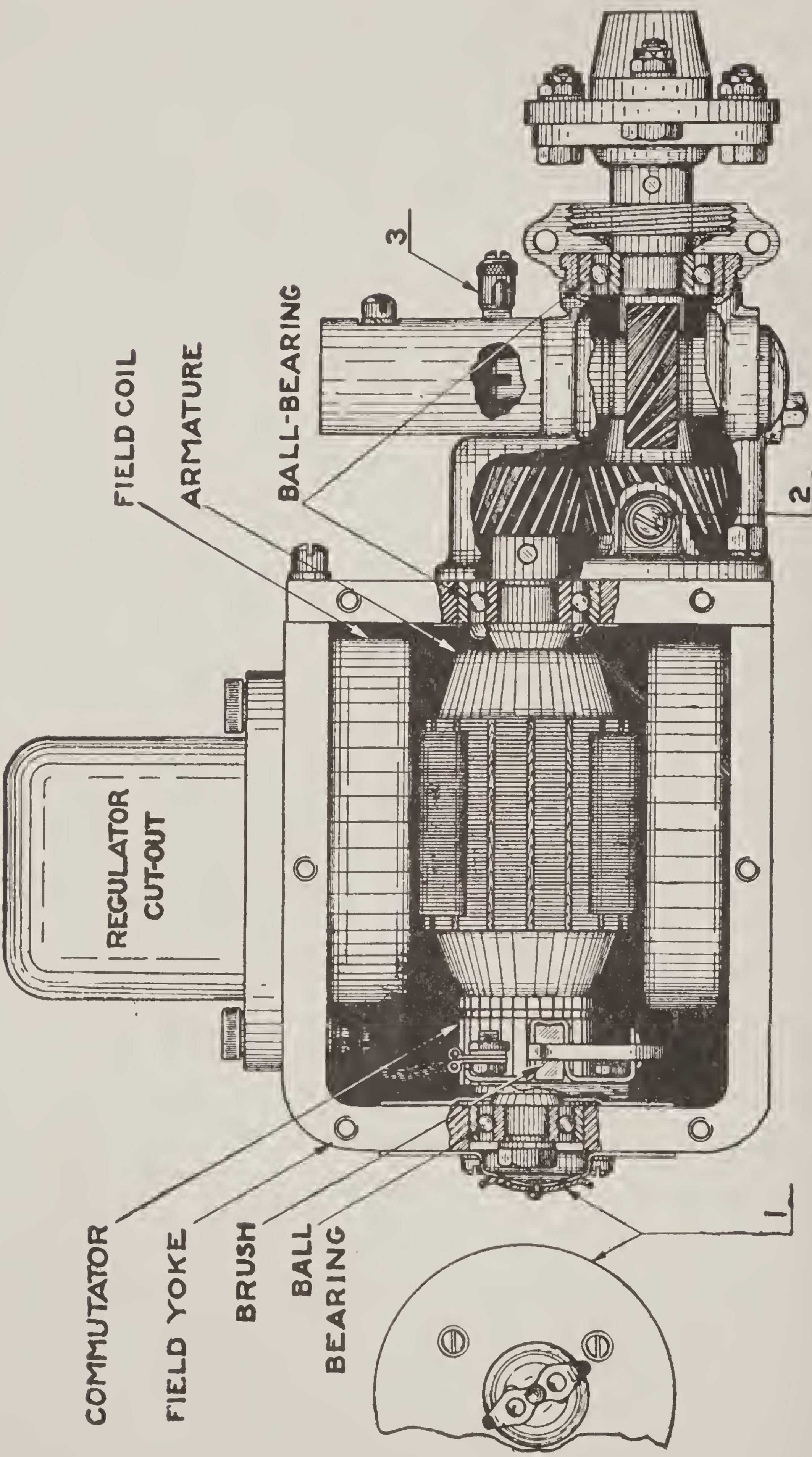


Fig. 281. Section of Gray & Davis Generator with Ignition Distributor Gearing (Shaft Drive)
Courtesy of Gray & Davis Company, Boston, Massachusetts

and only the excess current is charging the battery. Whenever the generator output drops below a point where it is supplying

sufficient current to light all the lamps that are on, the battery supplies the balance. The battery is thus said to be *floated on the*

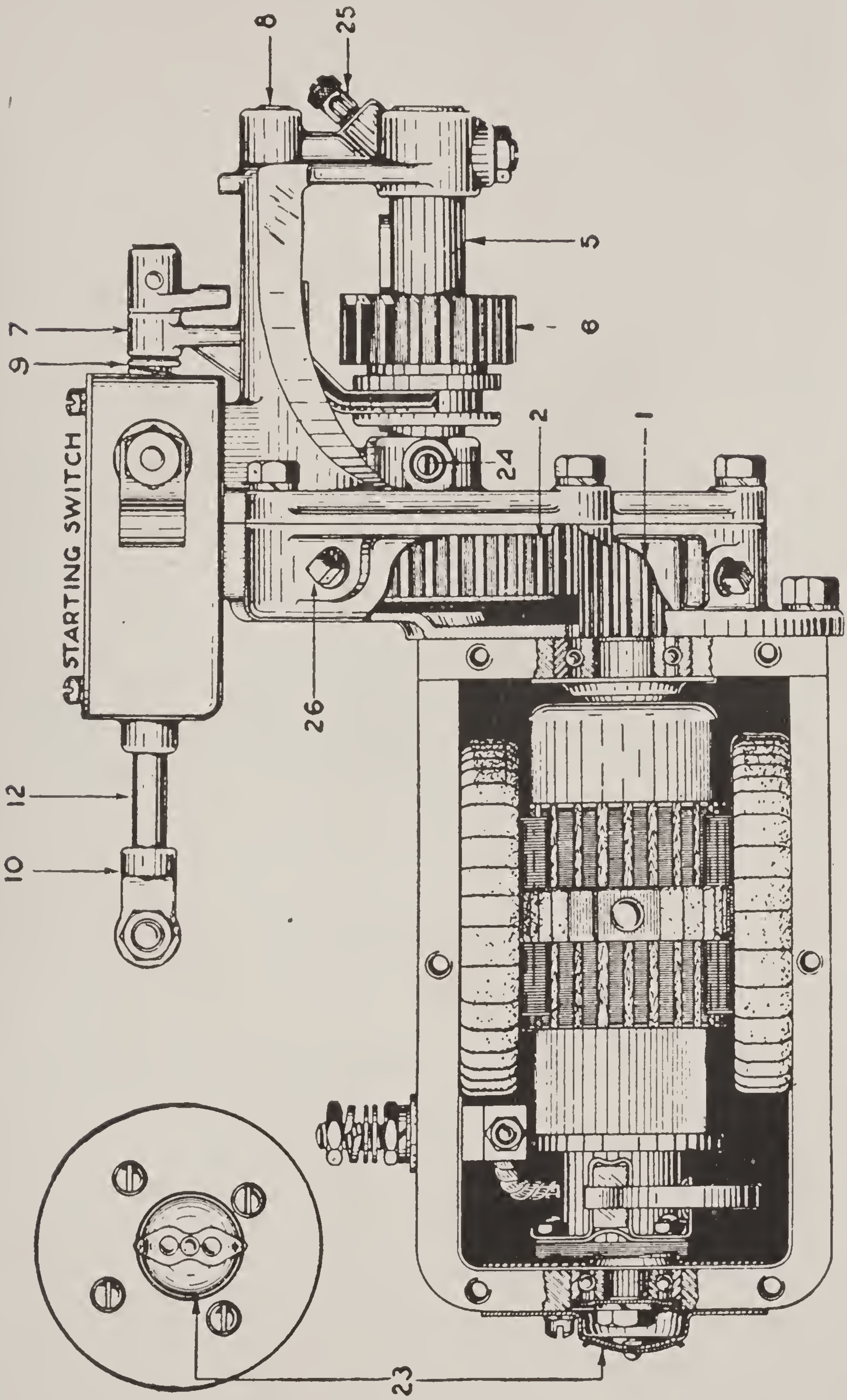


Fig. 282. Gray & Davis Starting Motor with Reduction Gearing for Open Flywheel. 1—Motor Pinion; 2—Intermediate Gear; 5—Intermediate Shaft; 6—Sliding Pinion; 7—Shifter Fork; 8—Shifter Rod; 10—Clevis; 12—Switch Rod; 23, 24, and 25—Oilers; 26—Oil Plug

line. It charges or discharges according to the current supply and the demand upon the latter.

Regulator Cut-Out. The regulator is of the constant-current type and on the Chandler, Metz, and Chalmers cars is set to allow the generator to produce a minimum of 8.5 amperes and a maximum of 11 amperes; on the Paige the minimum is the same, but the maximum is 12 amperes.

To Check for Adjustment. Insert the portable ammeter with the 30-ampere shunt in the circuit between the generator and the regulator and switch on all the lamps. Speed the engine up so that the generator is running above 1750 r.p.m. Open the upper set of points by inserting a match or using the finger, then adjust the lower set of points in accordance with the reading of the ammeter. Open the lower set and adjust the upper in the same way. Run the machine

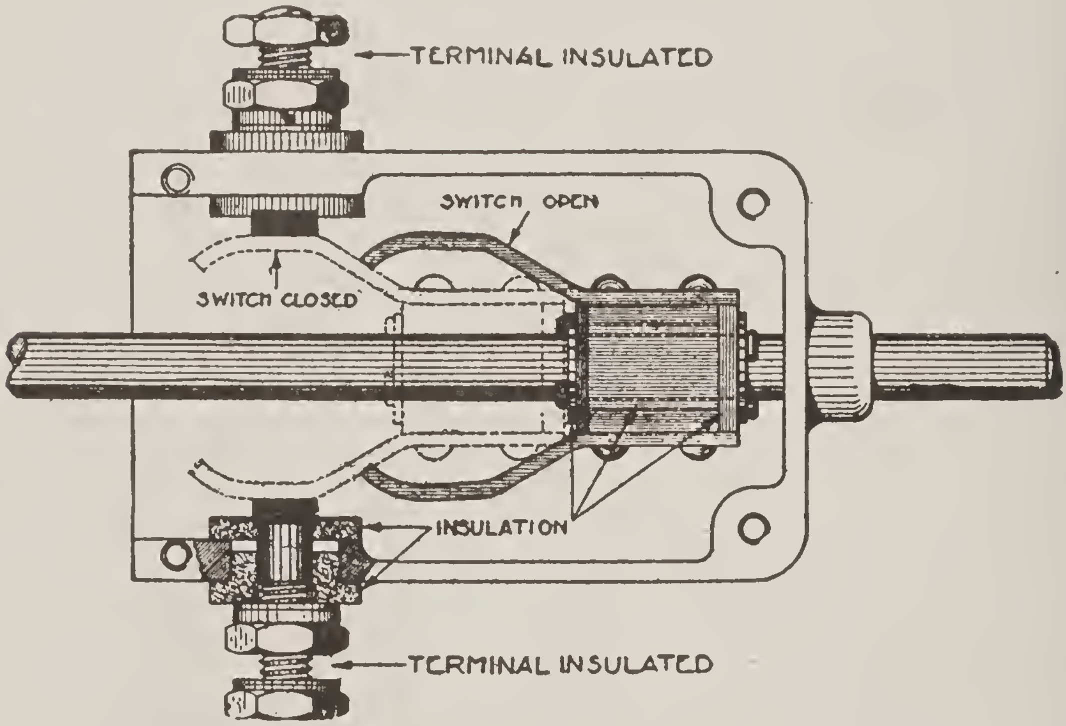


Fig. 283. Gray & Davis Starting Switch with Both Terminals Insulated

with both sets free, and the ammeter reading should fall within the limits above given.

To Check Candle Power of Lamps. These instructions are given by the manufacturers in connection with a special bench testing set using three 15-c.p. lamps in multiple. Check the candle power of the lamps on the car to see that their total does not exceed 45 c.p., as 25-c.p. headlights are sometimes used. The employment of headlights of this high power should be discouraged by the garage man, as they needlessly increase the load on the battery and cause a blinding glare.

To Check for Closing Voltage. The points of the battery cut-out are designed to close at $6\frac{1}{2}$ to 6 volts from the generator and are

designed to open on a current of ½ to 2 amperes from the battery on discharge. Connect the low-reading voltmeter, scale 1 to 10 volts, across the generator brushes. Gradually speed up the generator and note the voltmeter reading to determine the voltage at which the points close. If not correct, adjust the cut-out spring to bring the closing voltage within the above limits.

To Check the Cutting-Out Point. Connect ammeter in battery and cut-out circuit, using low-reading shunt, 1 to 3 amperes. Have the machine running at a speed at which points are closed, and gradually slow down, observing the ammeter reading when the points

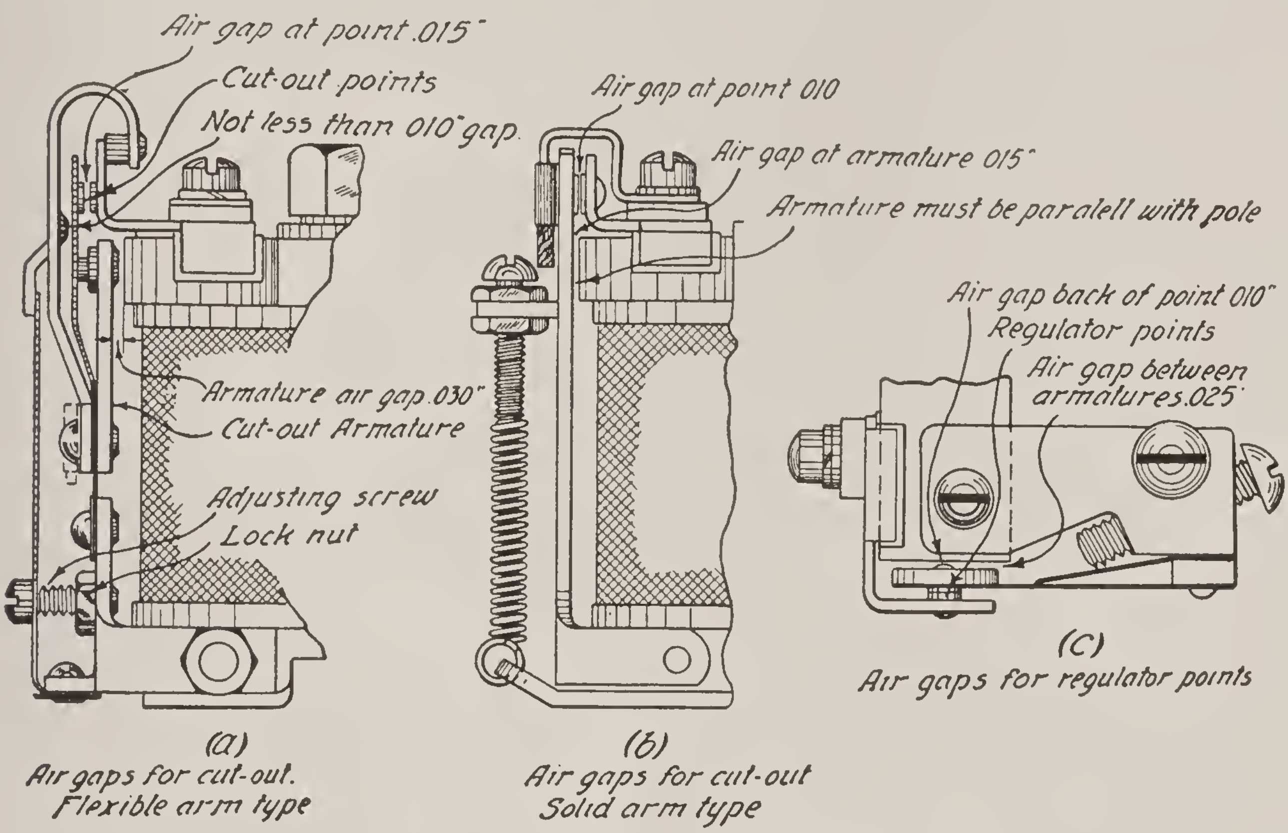


Fig. 284. Diagram Showing Air Gaps between Parts of Gray & Davis Apparatus

open. If not within the limits given, adjust the cut-out spring to bring them within these limits by tightening or loosening the spring tension and repeating the test. Should this not be possible, inspect the points to see if they are clean and true, and, if in good condition, check the distances of the various air gaps between the points and between the armature and the pole piece, or stop, as shown in Fig. 284.

Wiring Diagrams. The single-wire system is standard, but in some cases the motor is grounded and in others the switch. Among others, the Gray & Davis system with grounded motor is installed on the Peerless, Chandler, Stearns, and Winton; with grounded switch, it is installed on the Chalmers, Paige, and Maxwell. It is

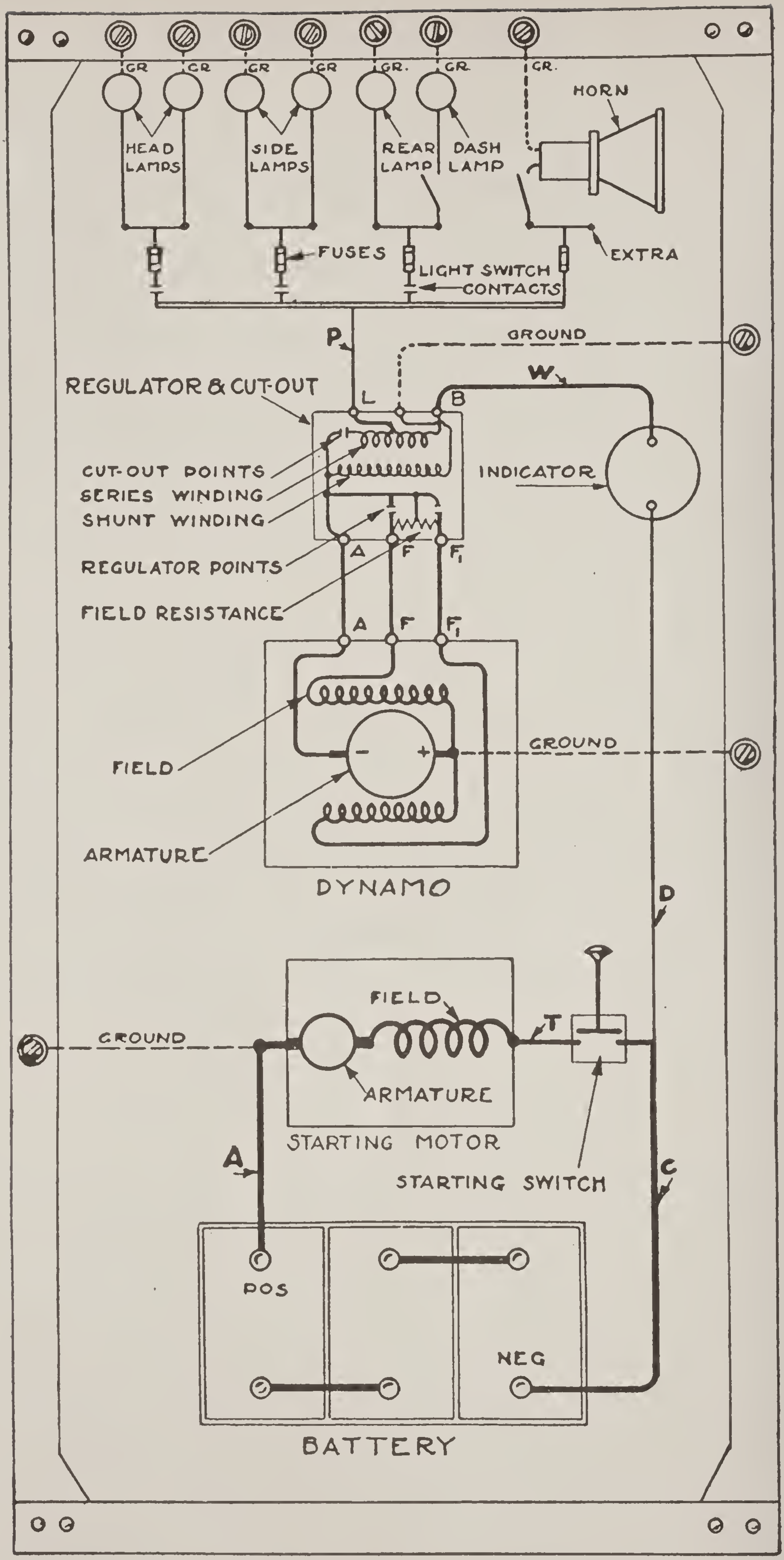


Fig. 285 Wiring Diagram for Gray & Davis Single-Wire System with Grounded Motor

naturally impossible to give complete lists of installations in any case, so that only one or two representative makes are mentioned to enable certain systems to be identified in the garage when desired.

Grounded-Motor Arrangement. Fig. 285 shows the Gray & Davis wiring diagram with grounded motor. Cable *A* from the battery positive terminal connects to the grounded terminal of the starting motor. Cable *T* connects an insulated terminal on the starting motor to one of the starting-switch terminals. Cable *C* from the starting switch terminal connects to the battery negative terminal, thus completing the circuit. On some makes of cars, cable *A* instead of

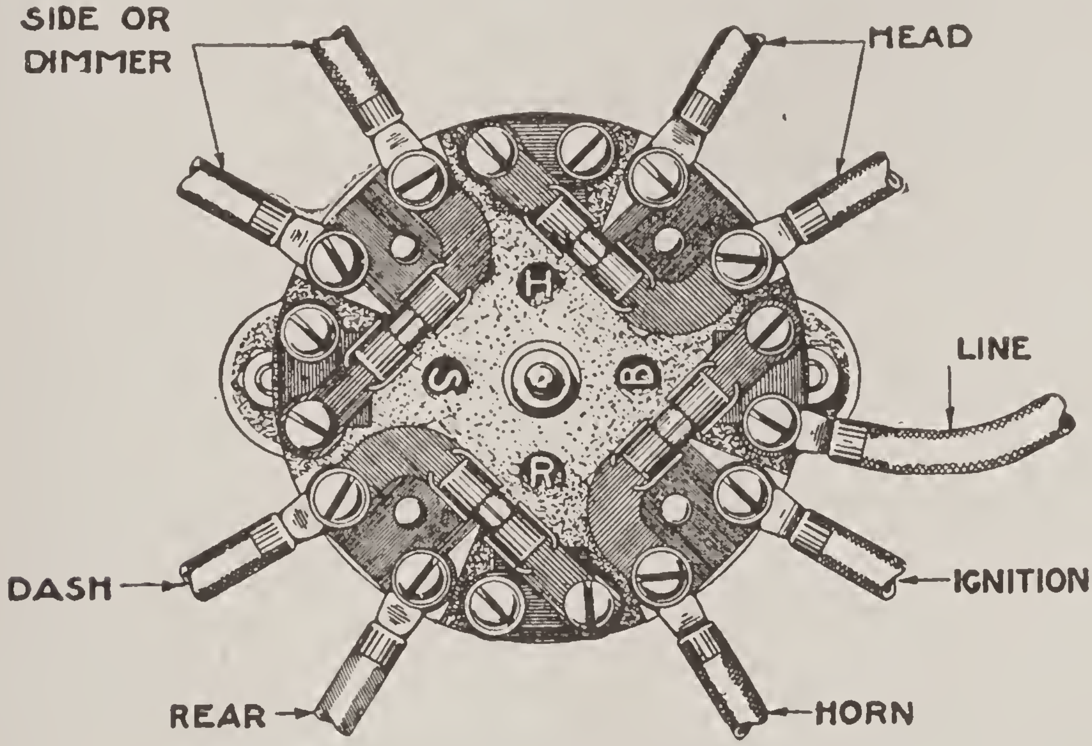


Fig. 286. Gray & Davis Lighting Switch, Rear View

connecting directly to the starting motor is connected to the frame of the car or *grounded.* The car frame carries the current to the grounded terminal of the starting motor. Wire *D* from the end of cable *C* at the starting switch connects to the lower terminal of the indicator (or ammeter). Wire *P* connects dynamo terminal *L* at the regulator to the lower terminal of block *B* at the lighting switch, Fig. 286 showing a rear view of the lighting switch. From the terminals at the fused side of *H* at the lighting switch, two wires connect to the right-hand and left-hand head lamps, while from the terminals at the fused side of *S* on the lighting switch corresponding wires connect to the two small lamps in the headlights. The tail lamp is connected from the fused side of *R* on the lighting switch and in some cases to the dash lamp, while the electric horn and ignition are

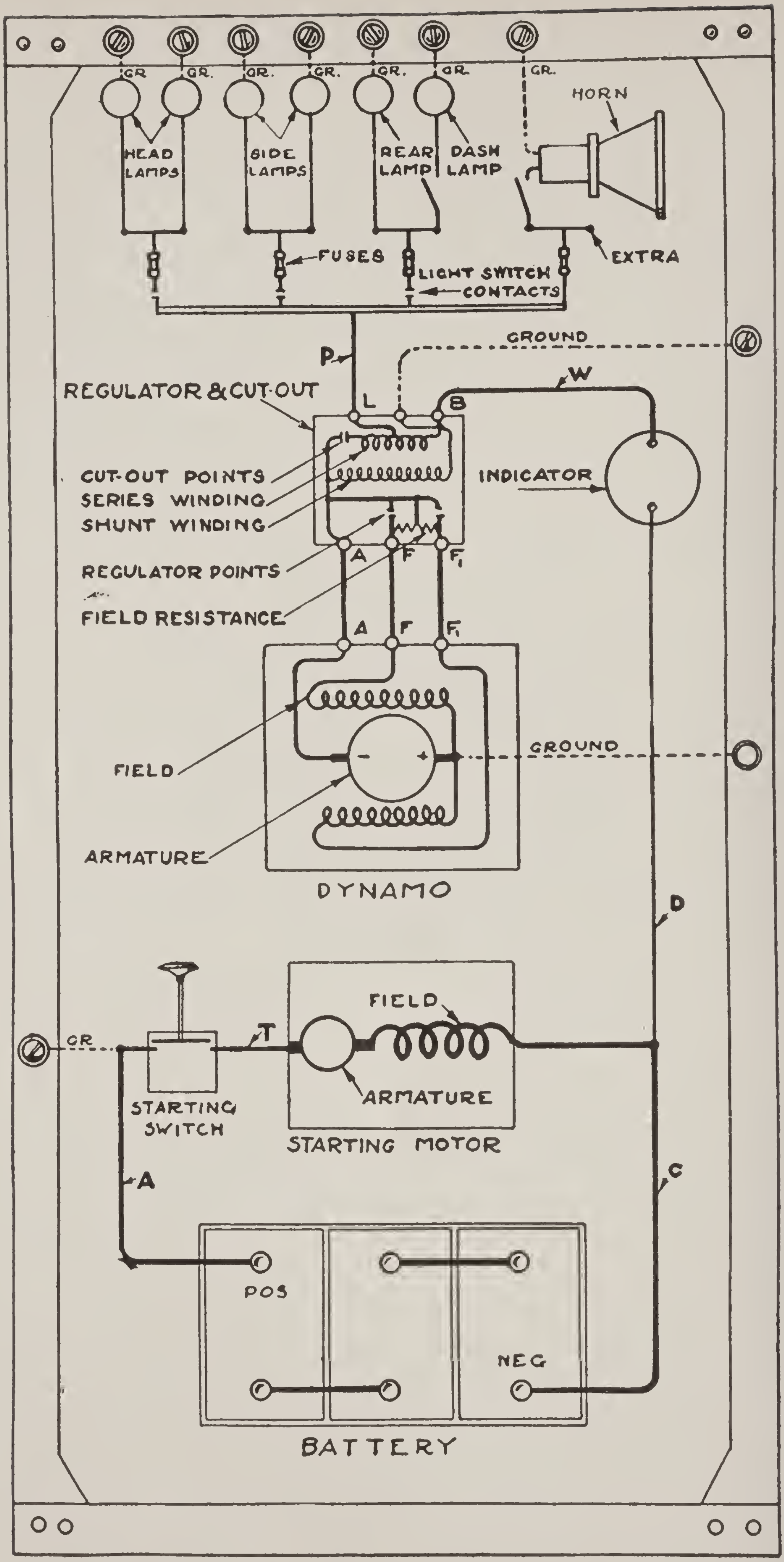


Fig. 287. Wiring Diagram for Gray & Davis Single-Wire System with Grounded Switch

connected to the fused side of *B*. The various ground connections are as follows: battery positive by cable *A* to frame at grounded terminal of starting motor; generator positive terminal to the frame of the dynamo itself; one side of all lamps to frame of car.

Grounded-Switch Arrangement. Fig. 287 is the Gray & Davis wiring diagram of the grounded-switch type. The only difference between this and the other diagram is that the ground connection is taken from the terminal of the cable *A* to the switch instead of from the motor.

Instructions. When the indicator does not indicate *charge* though the engine is speeded up, but indicates *discharge* with the engine stopped, the dynamo or the regulator may not be working properly. To verify this, turn on all the lights, run the engine at a speed equivalent to 10 miles per hour, disconnect the wire from terminal *B*, Fig. 285, at the regulator cut-out; if the lights fail, either the dynamo or the regulator is at fault. Reconnect the wire to terminal *B* and remove the side plate from the dynamo to examine the brushes. Slide the brushes in and out, and see that they slide freely in the brush holders and make good contact with the commutator and that the wires from the brush holders and the fields to the dynamo terminals are firmly connected. If the dynamo is belt-driven, the belt may not be tight enough to rotate the dynamo at sufficient speed to charge the battery. The commutator, if coated or dirty, may be cleaned while rotating by holding a cloth slightly moistened with oil against it.

Should these tests fail to remedy trouble, connect a wire at the regulator cut-out from terminal *A* to terminal *B*. With lights off, speed the engine to the equivalent of 10 miles per hour. If the indicator then shows *charge,* the regulator cut-out is at fault. Note whether any connections on it are loose or broken from vibration. See that the contacts are clean and come together properly. Take a match stick or small piece of clean wood and press them together; if this remedies the trouble, the contact points are at fault. Clean them with a strip of fine emery cloth or with a very small fine flat file, not taking off any more than is necessary to clean and true up the points. In case this treatment does not put the cut-out in working condition again, the manufacturer's service department should be called on for assistance.

But if, under conditions just given, the indicator, or ammeter, shows neither *charge* nor *discharge,* the dynamo circuit is open. This may be from poor brush contact or from a loose or broken connection at some other point. If the indicator shows *discharge,* reduce the engine speed to the equivalent of 8 or 9 miles an hour; then while the engine is running, connect another wire from the dynamo terminals F and F_1 to terminal A. If the indicator then shows *charge,* the regulator is at fault, as this wire cuts the regulator out of the charging circuit. While making this test, care must be taken not to run the engine any faster than mentioned, as the dynamo is not protected by the regulator. If in this test, the indicator still shows *discharge,* it signifies that the dynamo field circuit is open or that the armature is short-circuited.

Loose Connections. If with the engine speeded up the indicator does not show *charge* and with the engine stopped and the lights turned on it does not indicate *discharge,* there is an open or loose connection in the battery circuit. See that all the wires are firmly connected and that the contact faces are clean. Or the indicator itself may be at fault. Verify this by disconnecting one wire from it and if it then returns to neutral, it indicates that some part of the wiring is grounded on the frame of the car and is causing a short-circuit which is discharging the battery. But if after disconnecting this wire the indicator shows *discharge,* it is at fault. See if the pointer is bent. This probably will be the case if it indicates *charge* with the engine stopped.

Short-Circuits. If the ammeter discharge reading is above normal, it may indicate that higher candle-power lamps have been substituted for the standard bulbs, or that some of the lamp wires are short-circuited. Intermittent jerking of the pointer from *charge* to *neutral* while the engine is being speeded up also indicates a short-circuit. Repeated blowing of fuses indicates short-circuited lamp wires or defective lamps. Trace the wires along their entire length and try new bulbs.

Starting-Motor Faults. If the motor does not rotate, the battery may be discharged. In case the engine has been overhauled just before, main bearings may have been put up so tight that the starting motor has not sufficient power to turn it over. The starting switch may not be making good contact, the motor brushes may not be

bearing properly on the commutator, or the battery terminals may not be tight. If the starting motor rotates but does not crank the engine, the over-running clutch may not be running properly or the engaging gears do not mesh. When the starting motor cranks the engine a few turns and stops, the battery is almost discharged. Unless the engine starts after the first few revolutions, do not continue to run

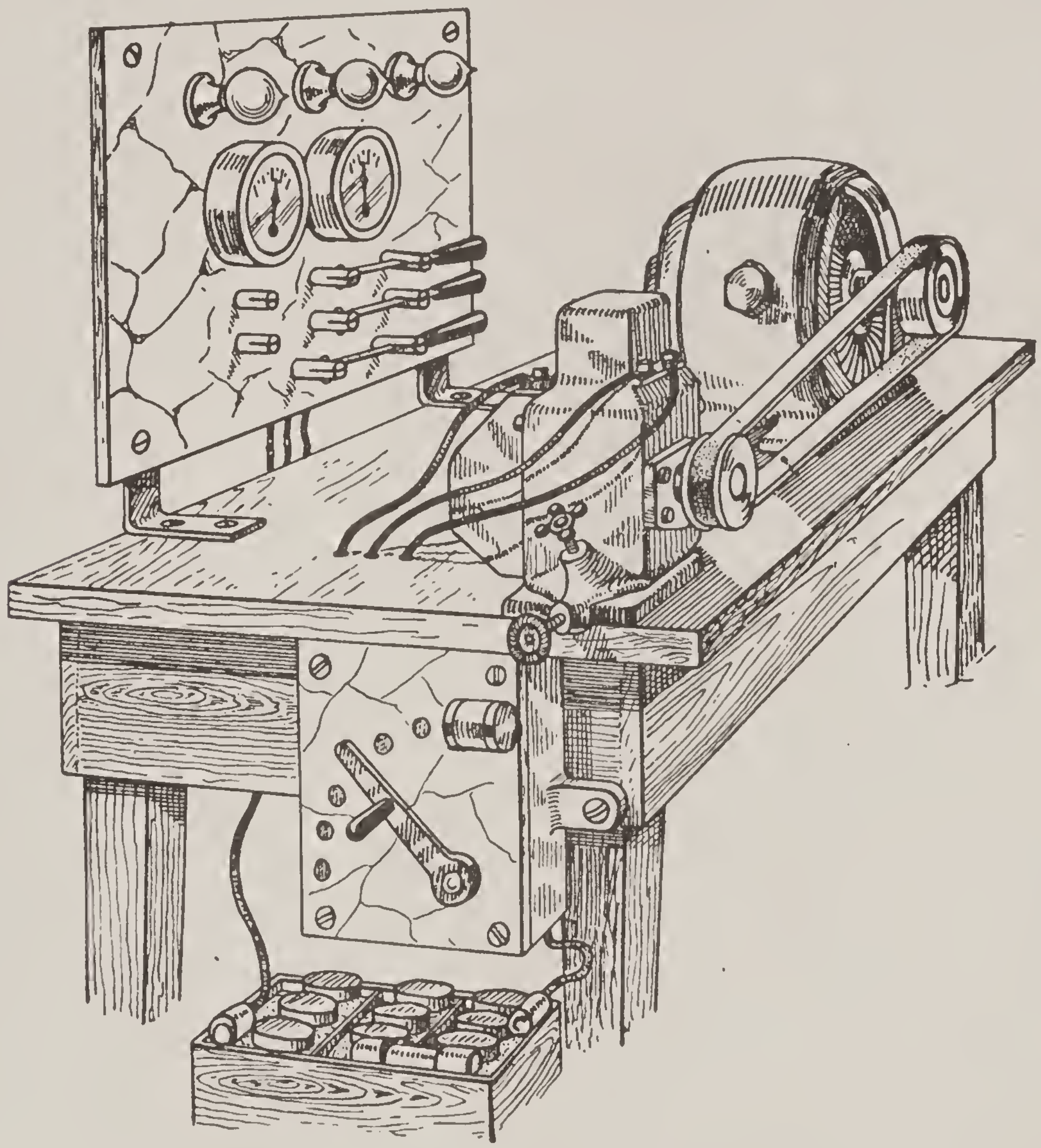


Fig. 288. Diagram of Layout for Testing Gray & Davis Generator
Courtesy of Gray & Davis, Boston, Massachusetts

the starting motor, as it will exhaust the battery very quickly. Look for causes of engine trouble—lack of gasoline, ignition circuit open, or the like.

Gray & Davis Service Tests. Garages caring for fifty or more cars find it profitable to install the equipment to carry out the necessary tests of electrical apparatus instead of referring every case that is beyond the ordinary requirements to the manufacturer or to one of its service stations. The makers recommend for testing generators and motors when removed from the car, the following apparatus:

(1) One $\frac{1}{2}$-h.p. electric motor with variable speed rheostat (direct current) giving a speed range of 600 to 1800 r.p.m. This is where only one machine is to be tested at a time; for running several from a countershaft, a 1- to 2-h.p. motor is necessary. (2) Three motor pulleys, 2, 3, and $7\frac{1}{2}$ inches in diameter, respectively, and three generator pulleys, $2\frac{1}{4}$, 3, and 5 inches in diameter. (3) Adjustable bases for holding generators. (These can be obtained from Gray & Davis.) (4) Portable voltmeter with a 15-volt scale. The instrument described for general testing will fill this requirement as well. (5) Ammeter with a charge and discharge reading to 25 amperes, i.e., 25—0—25. (6) One tachometer, or revolution counter. (7) Four Ediswan base sockets and three 15-c.p. 7-volt lamps. (8) One single-pole single-throw switch and two single-pole double-throw switches, all of 15-ampere capacity. (9) One 80-ampere-hour 6-volt storage battery. (10) Sufficient No. 10 flexible cable for making the necessary connections.

The above apparatus is more particularly for the generator tests. For making motor tests, the following are necessary:

(1) Ammeter reading to 400 amperes. (2) One spring scale reading to 20 pounds. (3) One single-pole single-throw switch of 200-ampere capacity. (4) Steel clamp and base for motor. (5) One 6-inch flanged iron pulley. (6) Sufficient No. 1 flexible cable for connections.

Generator Test Chart. In order to enable the tester to check the performance of the generator, the test chart, Table III, has been supplied. The method of mounting the $\frac{1}{2}$-h.p. motor, switches, instruments, rheostat, and storage battery is shown in Fig. 288, while the wiring diagram showing the method of connecting up the various units is illustrated in Fig. 289. Referring to the test chart, Table III, column 1 gives the types of generators manufactured by Gray & Davis. To determine the type number, it is necessary to note only the first three numbers on the name plate. For instance, 2221541 indicates type 222, machine 1541. This applies to all machines of this make turned out since September, 1915.

Column 2 shows the amount of current required to run the generator as a motor, or to "motorize" it. To take this reading, the posts *AF* and *F-1* should be connected together with a copper wire and the wire from the battery connected to the post *A*. The ampere reading and the speed should be within 10 per cent of the figures given in column 2. If not, remove the regulator and repeat the test, column 3 showing the proper speed. If the armature is shorted it will take excessive current, the ammeter needle will fluctuate, and the speed will be below normal. If the current is excessive but steady and the speed is high, it will show a defect in the fields or the field connections, as indicated in succeeding paragraphs.

TABLE III

Test Chart for Gray & Davis Generators

Information for Service Stations

1	2	3	4	5	6	7	8	9	10
Type of Generator	Running Light as a Motor at 6 Volts		Low Speed Reading 10 Amp.	Amperes Charge to Battery with 7½ Amp. Lamp Load		Shunt Field Current at 6 Volts		Output of Dynamo with 7½ Amp. Load	
	Amp.	Speed (r.p.m.)		Max.	Min.	Max.	Min.	Max.	Min.
Chandler S	3	320	750	4.5	1	1.32	1.09	11	8.5
Paige S	3	320	750	6	1	1.32	1.09	12	8.5
Chalmers T	3	650	1300	4.5	1	1.30	1.04	11	8.5
Metz T	3	650	1300	4.5	1	1.30	1.04	11	8.5
M.G.9	10	700	8 Amp. 1575	4.5	1	1.20	.96	11	8.5
300	10	700	8 Amp. 1575	4.5	1	1.20	.96	11	8.5
301	10	700	8 Amp. 1575	4.5	1	1.20	.96	11	8.5
210	3	320	750	6	1	1.32	1.09	12	8.5
211	3	650	1300	4.5	1	1.30	1.04	11	8.5
212	3	650	1300	6	1	1.30	1.04	12	8.5
213	3	650	1300	6	1	1.30	1.04	12	8.5
214	3	650	1300	6	1	1.30	1.04	12	8.5
216	3	650	1300	6	1	1.30	1.04	12	8.5
217	3	650	1300	6	1	1.30	1.04	12	8.5
218	3	650	1300	6	1	1.30	1.04	12	8.5
219	3	650	1300	4.5	1	1.30	1.04	11	8.5
220	3	300	600	4.5	1	1.02	.77	11	8.5
222	3	335	700	4.5	1	1.02	.77	11	8.5
223	3	335	700	6	1	1.02	.77	12	8.5
224	3	300	600	6	1	1.02	.77	12	8.5
225	3	300	600	4.5	1	1.02	.77	11	8.5
226	3	335	700	4.5	1	1.02	.77	11	8.5
227	3	650	1300	6	1	1.30	1.04	12	8.5
228	3	650	1300	4.5	1	1.30	1.04	11	8.5
229	3	335	700	4.5	1	1.02	.77	11	8.5
230	3	335	700	6	1	1.02	.77	12	8.5
231	3	335	700	6	1	1.02	.77	12	8.5
232	3	300	600	6	1	1.02	.77	12	8.5
233	3	335	700	4.5	1	1.02	.77	11	8.5
234	3	650	1300	4.5	1	1.30	1.04	11	8.5
235	3	150	1300	4.5	1	1.30	1.04	11	8.5
236	3	300	600	6	1	1.02	.77	11	8.5
237	3	320	750	4.5	1	1.32	1.09	12	8.5
238	3	650	1300	4.5	1	2.60	2.08	11	8.5
239	3	650	1300	4.5	1	2.60	2.08	11	8.5
240	3	335	700	4.5	1	2.04	1.54	11	8.5
241	3	335	700	4.5	1	2.04	1.54	11	8.5
242	3	335	700	4.5	1	2.04	1.54	11	8.5
243	3	335	700	4.5	1	1.02	.77	11	8.5
244	3	335	700	4.5	1	2.04	1.54	11	8.5
245	3	300	600	4.5	1	2.04	1.54	11	8.5
246	3	335	700	6	1	2.04	1.54	12	8.5
247	3	300	600	6	1	2.04	1.54	12	8.5
248	3	300	600	4.5	1	2.04	1.54	11	8.5
249	3	335	700	4.5	1	2.04	1.54	11	8.5
250	3	335	700	4.5	1	2.30	2.04	11	8.5
251	3	335	700	4.5	1	2.30	2.04	11	8.5
252	3	335	700	4.5	1	2.30	2.04	11	8.5
253	3	300	600	4.5	1	2.30	2.04	11	8.5
254	3	335	700	6	1	2.30	2.04	12	8.5
255	3	300	600	6	1	2.30	2.04	12	8.5
256	3	300	600	4.5	1	2.30	2.04	11	8.5
257	3	335	700	4.5	1	2.30	2.04	11	8.5
258	3	335	700	4.5	1	2.30	2.04	11	8.5
259	3	300	600	6	1	2.30	2.04	12	8.5
260	3	335	700	4.5	1	1.02	.77	11	8.5
261	3	300	600	6	1	2.30	2.04	12	8.5
262	3	300	600	6	1	2.30	2.04	12	8.5

Column 4 affords a check on other defects in the machine. To take this reading, connect posts *A F* and *F-1* together in order to give full field current, place machine on test bench, and run with belt. Speed the machine up until the ammeter indicates 10 amperes with the three 15-c.p. lamps in circuit and the battery testing 1.250 or over with the hydrometer. Take a reading of the speed. This should not be higher than that given in column 4. A higher reading will indicate defective fields, a high-resistance armature, pole pieces loose in frame, slight short-circuit in armature, defective brush or brush contact at commutator, or dirty commutator.

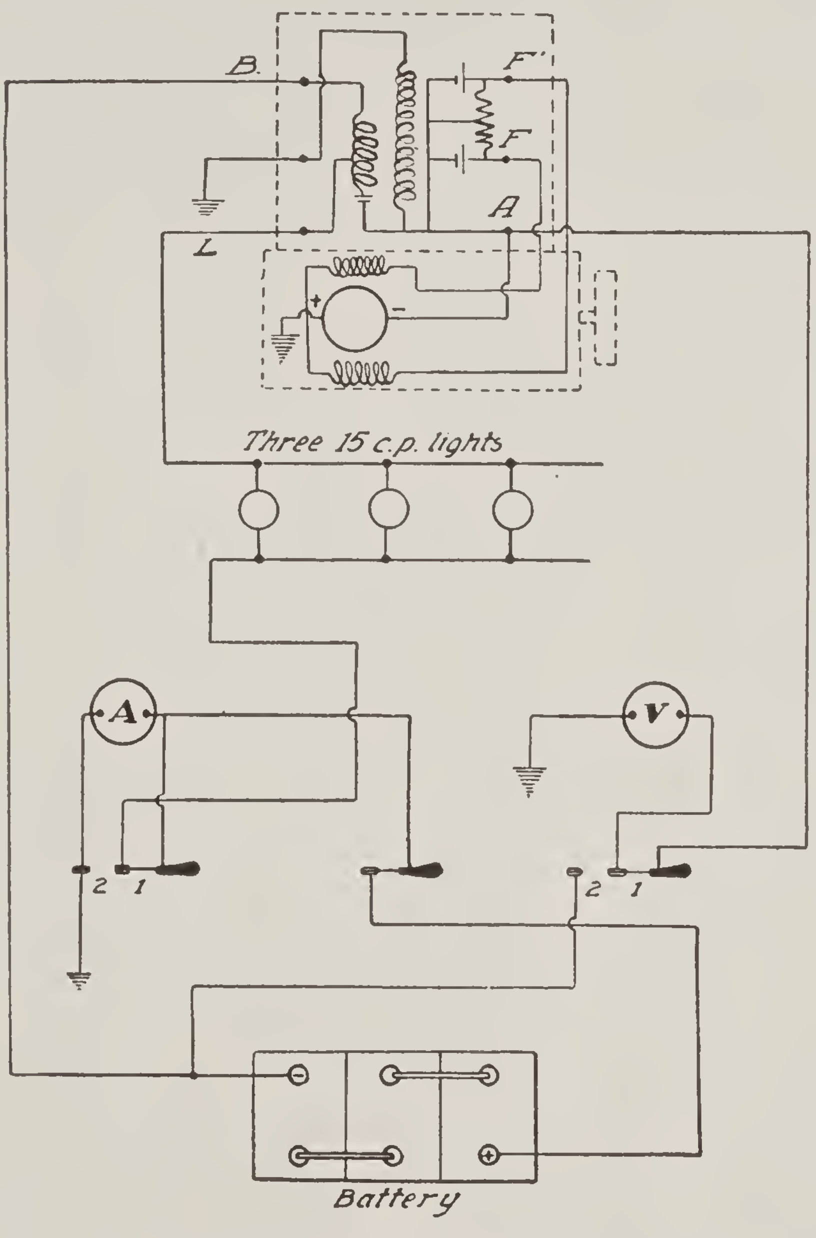


Fig. 289. Wiring Diagram for Gray & Davis Dynamo and Regulator

The purpose of columns 5 and 6 is to check the action of the regulator. To take this reading, turn on the three 15-c.p. lamps, giving a load of $7\frac{1}{2}$ amperes, and observe the amount of current passing into the battery with the ammeter switch in position *2*. The reading should be within the limits shown in columns 5 and 6.

Columns 7 and 8 show the current taken by the field coils. Connect one side of the battery to the frame of the generator and the other side through the ammeter to terminal *F*. The reading should not be greater than column 7 or less than column 8. Repeat the test at terminal *F-1*. A high reading will show a short-circuit, and a low reading will show a poor connection or a high resistance in the field. No reading at all will indicate an open circuit in the field.

TABLE IV

Test Chart for Gray & Davis Starting Motor

1	2	3	4	5	6	7	8	9
Type of Motor	Running Free Reading				Minimum Brush Pressure (lb.)	Gear Reduction in Gear Housing	$1\frac{1}{2}$ Lb. Torque Reading at $5\frac{3}{4}$ Volts	
	Max. Amp.	Speed 3 Volts	Speed 5.5 Volts	Speed 6 Volts			Amperes	Speed (r.p.m.)
100	35	3500	6600	7000	$3\frac{1}{2}$	None	137	2400
101	35	3500	6600	7000	$3\frac{1}{2}$	49–14	137	2400
102	35	3500	6600	7000	$3\frac{1}{2}$	47–16	137	2400
103	35	3500	6600	7000	$3\frac{1}{2}$	50–13	137	2400
104	35	3500	6600	7000	$3\frac{1}{2}$	50–13	137	2400
105	35	3500	6600	7000	$3\frac{1}{2}$	84–12	137	2400
106	35	3500	6600	7000	$3\frac{1}{2}$	51–12	137	2400
107	35	3500	6600	7000	$3\frac{1}{2}$	51–12	137	2400
108	35	3500	6600	7000	$3\frac{1}{2}$	50–13	137	2400
109	35	3500	6600	7000	$3\frac{1}{2}$	50–13	137	2400
110	35	1900	3800	4100	$3\frac{1}{2}$	51–24	98	1980
113	35	3500	6600	7000	$3\frac{1}{2}$	50–13	137	2400
115	35	3500	6600	7000	$3\frac{1}{2}$	50–13	137	2400
116	35	3500	6600	7000	$3\frac{1}{2}$	51–12	137	2400
117	35	3500	6600	7000	$3\frac{1}{2}$	51–12	137	2400
118	35	3500	6600	7000	$3\frac{1}{2}$	50–13	137	2400
119	35	2200	4500	5000	$2\frac{1}{4}$	None	100	1660
120	35	2200	4500	5000	$2\frac{1}{4}$	Direct	100	1660
121	35	2200	4500	5000	$2\frac{1}{4}$	Direct	100	1660
122	35	1900	3800	4100	$3\frac{1}{2}$	Direct	98	1980
123	35	3500	6600	7000	$3\frac{1}{2}$	49–14	137	2400
124	35	3500	6600	7000	$3\frac{1}{2}$	51–12	137	2400
125	35	3500	6600	7000	$3\frac{1}{2}$	50–13	137	2400
126	35	2200	4500	5000	$2\frac{1}{4}$	Direct	100	1660
127	35	2200	4500	5000	$2\frac{1}{4}$	Direct	100	1660
128	35	3500	6600	7000	$3\frac{1}{2}$	51–12	137	2400
129	35	2200	4500	5000	$2\frac{1}{4}$	54–12	100	1660
130	35	2200	4500	5000	$2\frac{1}{4}$	Direct	100	1660
131	35	2200	4500	5000	$2\frac{1}{4}$	Direct	100	1660
132	35	2200	4500	5000	$2\frac{1}{4}$	Direct	100	1660
133	35	3500	6600	7000	$3\frac{1}{2}$	50–13	137	2400
134	35	3500	6600	7000	$3\frac{1}{2}$	50–13	137	2400
135	35	3500	6600	7000	$3\frac{1}{2}$	49–14	137	2400
136	35	3500	6600	7000	$3\frac{1}{2}$	49–14	137	2400
137	35	3500	6600	7000	$3\frac{1}{2}$	50–13	137	2400
138	35	2230	4500	5000	$2\frac{1}{4}$	Direct	100	1660
139	35	2230	4500	5000	$2\frac{1}{4}$	Direct	100	1660
140	35	2230	4500	5000	$2\frac{1}{4}$	Direct	100	1660
141	35	1900	3800	4100	$3\frac{1}{2}$	Direct	98	1980
142	35	1900	3800	4100	$3\frac{1}{2}$	51–24	98	1980

Columns 9 and 10 show the current output for which the generator is set at the factory. To test this, place the ammeter switch in position *1* and with the three 15-c.p. lamps turned on speed the machine above 1750 r.p.m. If the reading does not fall within

the limits given, adjust the regulator in accordance with instructions given below.

Starting-Motor Test Chart. Table IV is provided for reference in cases where the motor trouble is of such a nature that it cannot be located except by a test, i.e., in the windings. Column 1 gives the types of starting motors, which may be identified in manner the same as the generators. The type number covers the motor and the speed reducer.

Column 2 shows the current required to run the motor free. The reading should not vary by more than 25 per cent from the figures given. A high reading will indicate tight bearings, short-circuited armature, or field.

Columns 3, 4, and 5 show the speed when running light with current at 3 volts, $5\frac{1}{2}$ volts, and 6 volts. The test should be made with either two or three cells of the battery. A low-speed reading with normal current will indicate loose connections, poor brush contact, dirty commutator, or high resistance in armature. A high-speed reading will indicate a short-circuit in the field windings.

Column 6 gives the spring pressure on the brushes. Where the brushes show a tendency to spark, this brush pressure should be checked. This reading is taken with a small spring scale hooked on to the brush screw. Read the number of pounds required to just lift the brush from the commutator. The reading should not be less than the figures given in column 6. Column 7 gives the reduction between the starting-motor shaft and the countershaft which carries the sliding gear.

Columns 8 and 9 are readings showing whether or not the motor is capable of delivering its rated power on normal current consumption and at normal speed. The reading is taken by putting on the shaft a load requiring a turning power of $1\frac{1}{2}$ pounds at a 1-foot radius. To take this reading the flanged pulley, spring scale, and a cord are employed in the manner shown in Fig. 290. The reading on the scale corresponding to $1\frac{1}{2}$ foot-pounds will be 6 pounds. Thus: $1\frac{1}{2}$ foot-pounds times 12 inches equals 18 inch-pounds, which divided by 3 inches (radius of pulley) gives 6 pounds (scale reading).

To take the reading, close the switch and put just enough tension on the cord *A* to make the scale read 6 pounds and, holding this steady, read volts, amperes, and speed. The speed given in column 9

is taken at $5\frac{3}{4}$ volts, which is what would be obtained with a battery showing 1,250 or over on the hydrometer test. A lower voltage will cause a lower speed reading. In the majority of cases, tests made with the motor running free will show any defects, but in case these tests do not reveal any trouble and the motor still fails to operate satisfactorily, the tests for which the proper figures are given in columns 8 and 9 should be carried out.

To Adjust Cut-Out. The contact points should close to permit the battery to charge at 6 to $6\frac{1}{2}$ volts; they should open the circuit between the battery and the generator on a discharge of $\frac{1}{2}$ to 2

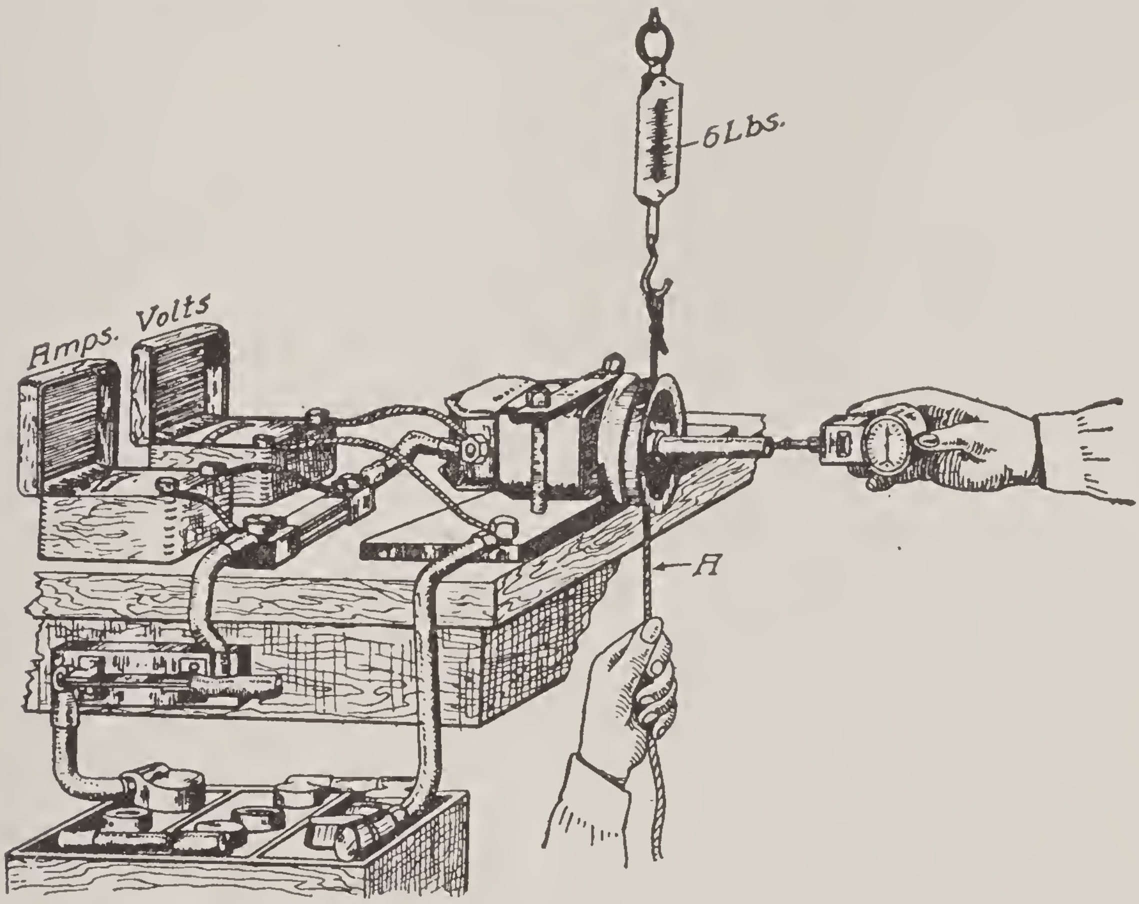


Fig. 290. Set-Up for Testing Power of Motor
Courtesy of Gray & Davis, Boston, Massachusetts

amperes. To test the cut-out, connect the voltmeter across the generator brushes or have the voltmeter switch in position *1*, Fig. 289. Gradually speed up the generator and observe the voltmeter to determine the closing voltage. The closing voltage is the reading on the voltmeter at the instant that the cut-out points come together. Adjust the cut-out spring to bring the closing voltage within the limits given above. With the lamps turned off and the ammeter switch in position *1*, slow the machine down and observe the ammeter reading when the cut-out points open. Adjust the cut-out spring to make this reading fall within the above limits. In case a satisfactory result is

not obtainable after several attempts at adjusting the spring, check the air-gap distances, as given below. Correct these and test again.

To Adjust Regulator. With all connections made and the ammeter switch in position *1*, turn on the three 15-c.p. lamps and speed the machine up to above 1750 r.p.m. Open the upper set of points with the aid of a match or by using the finger. Adjust the lower set of points by the ammeter reading so as to bring it within the limits given in columns 9 and 10 of the generator test chart. Repeat the adjustment on the upper set, opening the lower set while the test is being made. Run the machine with both sets of points free and the reading should fall within the limits given in columns 9 and 10.

HEINZE-SPRINGFIELD SYSTEM

Six-Volt; Two-Unit; Single-Wire

Generator. The generator is of the multipolar shunt-wound type (four poles) with brushes spaced 90 degrees apart, bringing both on the left side of the commutator to make them more accessible. The negative, or lower, brush of the generator, Fig. 291, is grounded to the brush holder, which, in turn, is grounded on the generator brush head. From the positive, or upper, brush a wire runs to the terminal GEN. BR.+ of the regulator and cut-out, Fig. 292. From this terminal, the charging circuit leads to the cut-out contacts and through the latter and the series winding to the terminal BAT+ of the regulator cut-out. As the negative brush of the generator is grounded, the negative terminal of the battery and one side of all the lights are grounded. One end of the generator shunt field is grounded inside to the generator frame. The other end comes out through the hole provided for it in the brush head, runs to the terminal FLD of the regulator cut-out, and thence to the contacts of the current regulator if they are closed, or through a resistance if they are open.

Starting Motor. The starting motor is of the four-pole series-wound type with the brushes at 90 degrees apart, as on the generator. The positive brush is on top of the commutator and carries a terminal to which is connected the starting cable. The lead from the negative brush divides, part of the current passing around two of the four poles to the ground, while the other part passes through the other two poles to the ground connection. On starting motors bearing serial numbers

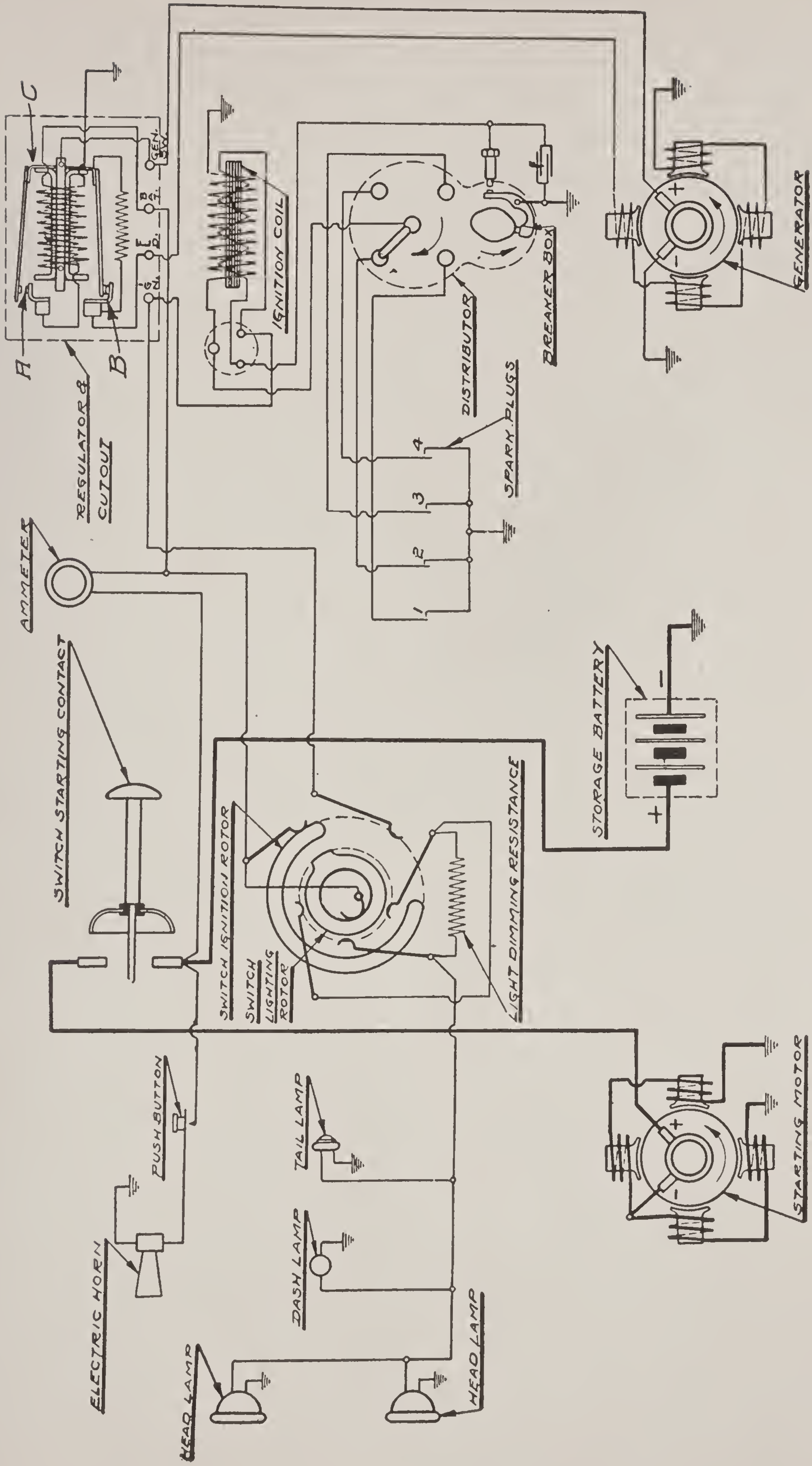


Fig. 291. Internal and External Wiring Diagram for Heinze-Springfield System on Regal Car

below 5471, the grounded ends of the series fields were soldered to the pole pieces, but this has since been altered by securing the two ends of the series field to a ground lead, which, in turn, is secured to the bottom of the motor brush head by means of a hexagonal nut and lock washer.

While the system is of the two-unit type and the units are independent of each other electrically, they are combined mechanically by making the rear heads of both in one casting. The starting motor is the upper of the two units, the lighting generator being placed directly beneath it. This refers to the set supplied for installation on the Ford.

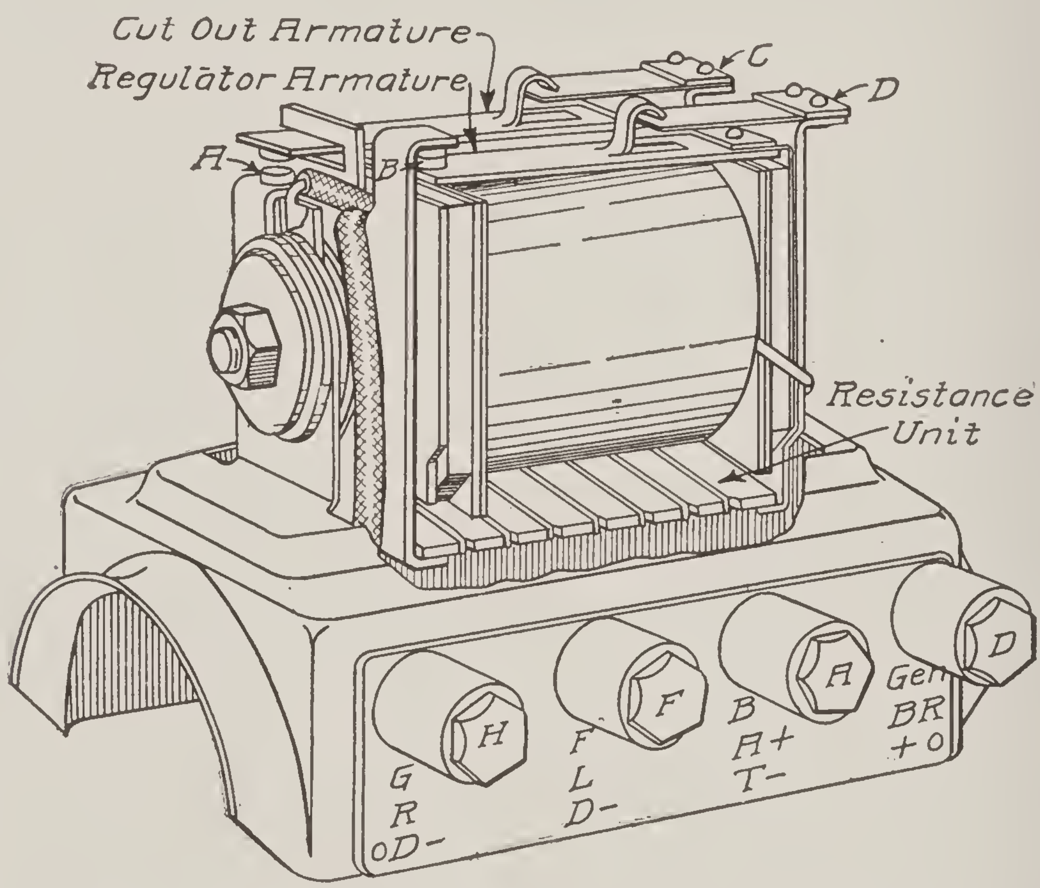


Fig. 292. Heinze-Springfield Current Regulator and Battery Cut-Out

Method of Operation. Drive is by means of a silent chain directly to the sprocket on the generator shaft. In addition to the sprocket in question, the generator shaft carries also a large gear adapted to mesh with the small pinion on the shaft of the Bendix drive mounted on the shaft of the starting motor. When the starting motor rotates, the Bendix pinion automatically engages the gear on the generator shaft and drives to the engine through the silent chain, the engagement being broken as soon as the engine turns over under its own power.

Regulation. *Voltage Regulator and Resistance.* The current regulator is combined with the battery cut-out and the combined unit

is mounted directly on the starting motor, Fig. 292. The regulator side of the relay consists of two contacts *B*, which are normally held together by spring tension so that the charging current does not exceed 10 to 12 amperes. When the voltage rises above a certain value owing to the increased speed of the engine, the regulator armature is drawn down, separating the contacts, and the current must then pass through the resistance unit shown beneath the coil. This keeps the charging current down to the value mentioned.

On the battery cut-out side, the relay consists of two contacts *A*, which are normally held apart by spring tension when the engine is not running or is running too slowly to charge the battery. As soon as it is running fast enough to generate sufficient voltage to overcome that of the storage battery, the regulator armature is drawn down, closing the contacts. This occurs at an engine speed equivalent to about 6 miles per hour, at or above which the battery is always charging. When the speed decreases to below this point, the pull on the armature is not sufficient to hold it down, and the contacts are separated by the spring *C*.

Starting Switch. The starting switch is a combination dash switch designed to control the starting, lighting, and ignition. In the Ford set, the current for starting and lighting is furnished by the battery, while the current for ignition comes from the Ford magneto. Starting is accomplished by depressing the button in the center of the switch, while the lights are controlled by rotating the switch lever. By rotating the switch lever, the ignition rotor connects the contacts *M* and *C*, Fig. 399, in the IGN. ON position and allows current to flow from the magneto through the switch, coil, and plug connections. The lighting rotor of the switch is always supplied with current from the battery through a sliding contact of the wiping type. When at the "Lights Dim" position, the current passes through the dimming resistance, the ignition remaining undisturbed by this change. The switch is designed to lock both the starting contact and the lighting and ignition lever in the IGN. OFF "Lights Dim" position for parking at night, and in the OFF position for the daytime.

Instruments and Protective Devices. Unless specially ordered, an ammeter is not provided with the system designed for the Ford but may be had at an extra cost in the form of a combination panel

carrying the switch, the ammeter, and a dash light. The regulator and the cut-out serve to protect the generator and the battery, respectively.

Wiring Diagram. As installed on the Ford, including an ammeter and dash lamp as just mentioned, the details of the wiring are shown in Fig. 401. The negative side of both the generator and the starting motor are grounded, the connection being split in the latter case and two grounds made. The negative side of the battery and one side of all the lamps and the horn as well are accordingly grounded. As ignition current is supplied by the magneto, the only connection of the ignition system with the lighting and starting system is at the combination switch. The charging current from the generator passes through the regulator (lower set of contacts) and when the engine is running at a speed equivalent to 6 miles an hour or more, the armature of the cut-out is pulled down and the upper set of contacts closes. This sends the charging current through the battery. Should the car be driven at a speed which causes the output of the generator to exceed 10 to 12 amperes, the regulator armature is attracted and the regulator contacts separate, thus shunting the current through a resistance which immediately serves to decrease the excitation of the generator fields and correspondingly reduces the current output of the latter. When the speed of the engine drops below a point where the voltage generated is insufficient to charge the battery, the cut-out contacts are separated by the spring, as the pull of the magnet is then not strong enough to hold it down. The lights are supplied directly from the battery, as will be noted, the diagram making clear the various positions of the rotating switch to give the different combinations available. The various connections and their significance will be clear upon comparing this with other and similar wiring diagrams.

Instructions. Failure of the starting motor to operate is usually caused by lack of current in the storage battery, although this fault may be due to several causes, acting either separately or together. Lack of charge in the battery is usually caused by over-frequent use of the starting system with but little driving between, so that the generator is not given an opportunity to charge the battery. Other causes of failure are treated under Starting and Lighting Storage Batteries, in another section.

Starting Motor. The starting motor may not operate because of internal trouble. This may take the form of an open- or short-

circuited armature or field, dirty commutator, insufficient tension on brushes, brushes not bearing on commutator, or grounded brush holders, armature, or field. Of these various causes of failure, the first is liable to be the most rare. For their correction see the various sections on testing for grounds and short-circuits with the aid of the ammeter also on care of commutator and brushes, given in connection with the description of other systems. The attention required is identical in practically every case and, where the brushes and the commutator are concerned, does not vary even in detail on the different systems.

Bendix Drive. Failure of the Bendix drive to operate properly may be due to lubricating the screw shaft, on which no oil or grease is necessary, since it will work better without it. Putting oil on this shaft makes impossible the "running start", which is the great advantage of the Bendix drive, i.e., the starting motor should almost instantly attain a high speed the moment the current is turned on, but the Bendix pinion will not move for a perceptible interval. When the Bendix pinion does move, the starting motor is running so fast that, at the moment the pinion engages suddenly, owing to the action of the spring, the engine is turned over the first compression very much easier than if the motor had to start nuder load.

Generator. Trouble in the generator will usually be manifested by the failure of the machine to generate a terminal voltage. The first warning would be the absence of any reading at the ammeter when the generator should be charging, the engine then running at a speed equivalent to 6 miles an hour, or over. If no ammeter is employed, the discharged condition of the battery may be traced either to the generator or to failure to drive the car sufficiently during the daytime and between starts to keep the battery charged. If, upon test with the hydrometer, the battery indicates rapid recuperation after the engine has been running for 15 to 30 minutes, the generator is not at fault. Should the battery specific-gravity test not show any improvement after running 30 minutes, the fault may be either in the generator or in the regulator cut-out. As is the case with the starting motor, defects in the generator may take the form of a dirty commutator, badly worn brushes, insufficient tension of brush springs to keep the brushes bearing on the commutator; the positive brush may be grounded; or there may be open-circuits or

grounds, or short-circuits or grounds in the field or armature. In any case, the attention necessary will be the same as that already outlined for similar faults on other systems.

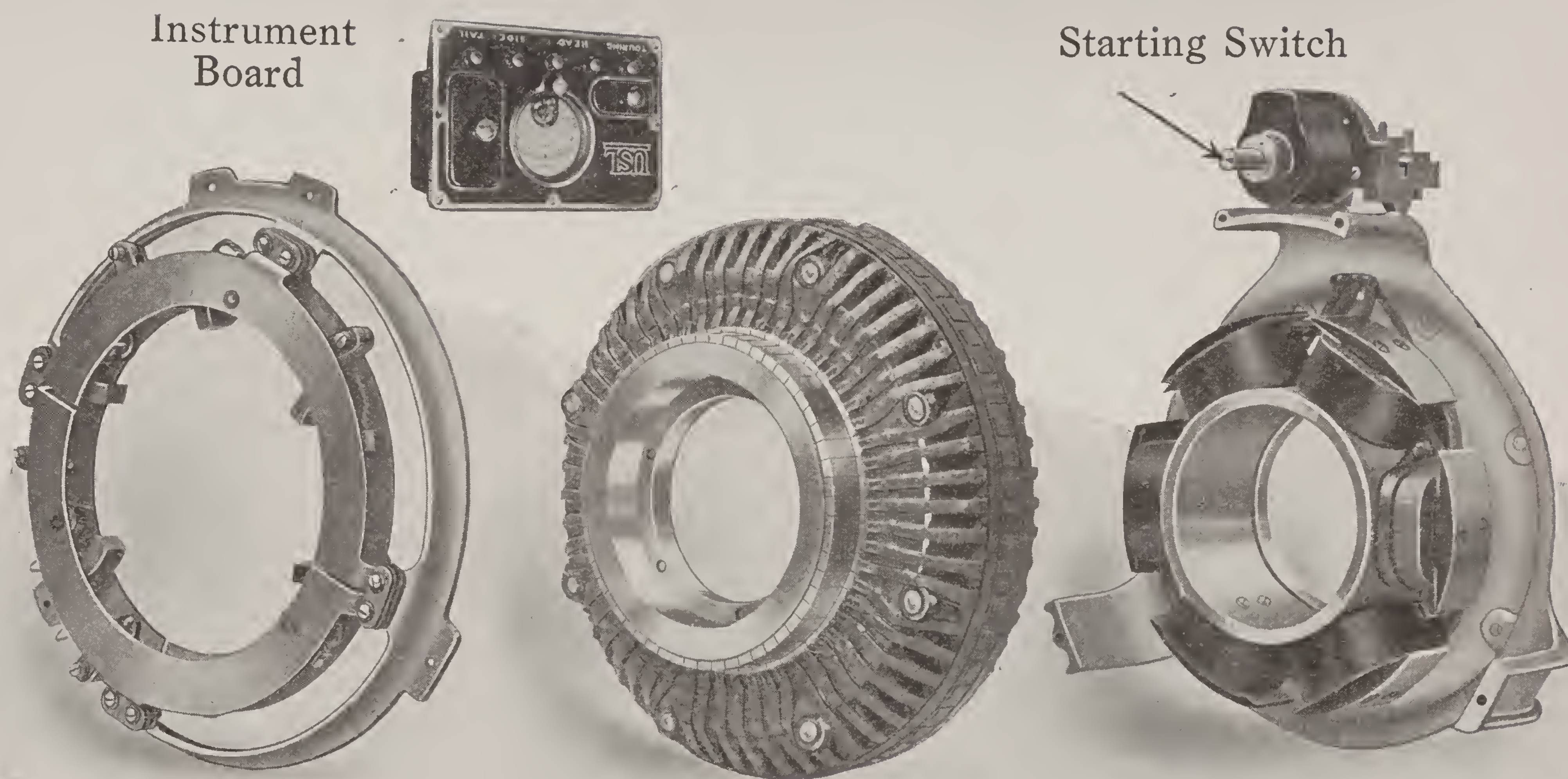
Regulator and Cut-Out. The regulator and cut-out consist of a single electromagnet with a split core on which there are two windings. The primary is in series with main charging circuit and the secondary is shunted across the motor brushes. If the generator is at fault, the battery cut-out naturally will not work, as there will be no voltage to operate it; but there will be times when the generator is working all right and the regulator is at fault, although it may be difficult at first sight to make sure which is the cause of the trouble. To determine this, with the engine running at a speed equivalent to 6 miles an hour or more, press the battery cut-out contacts together with the fingers. If the ammeter then shows a charge reading, and there is no dash ammeter, a weight may be placed on the cut-out armature to keep the contacts together for 30 minutes or so, and if the battery then shows that it is charging, the cut-out and not the generator is at fault. If, with the cut-out contacts thus held together, there is no sign of charging the battery, the generator is the cause of the trouble.

To adjust the regulator and cut-out, first adjust the regulator side, as the cut-out is dependent upon the regulator adjustment. Before starting the engine, remove the regulator and the cut-out cover, then remove the wire to the terminal "BAT+" and insert an ammeter in the charging circuit at this point, though if there be an ammeter on the dash, it may be used. Start the engine and run it very slowly. See that the regulator contacts are together, Fig. 292. At a speed equivalent to 6 miles an hour or over, the cut-out contacts *A* should close, and with the contacts at *B* closed, the ammeter should show a reading of 4 amperes. If contacts *A* do not close at this point, there may be too much tension on the spring, which may be remedied by bending the spring-holding support upward at *C*. Should the ammeter reading go above 10 to 12 amperes as the speed increases, this is due to the contacts *B* of the regulator not opening as they should. The tension of the armature spring of the regulator should then be lessened by bending the spring-holding support slightly upward at *D*. Note very carefully as the engine speed is decreased that there is enough spring tension on the cut-out armature to open

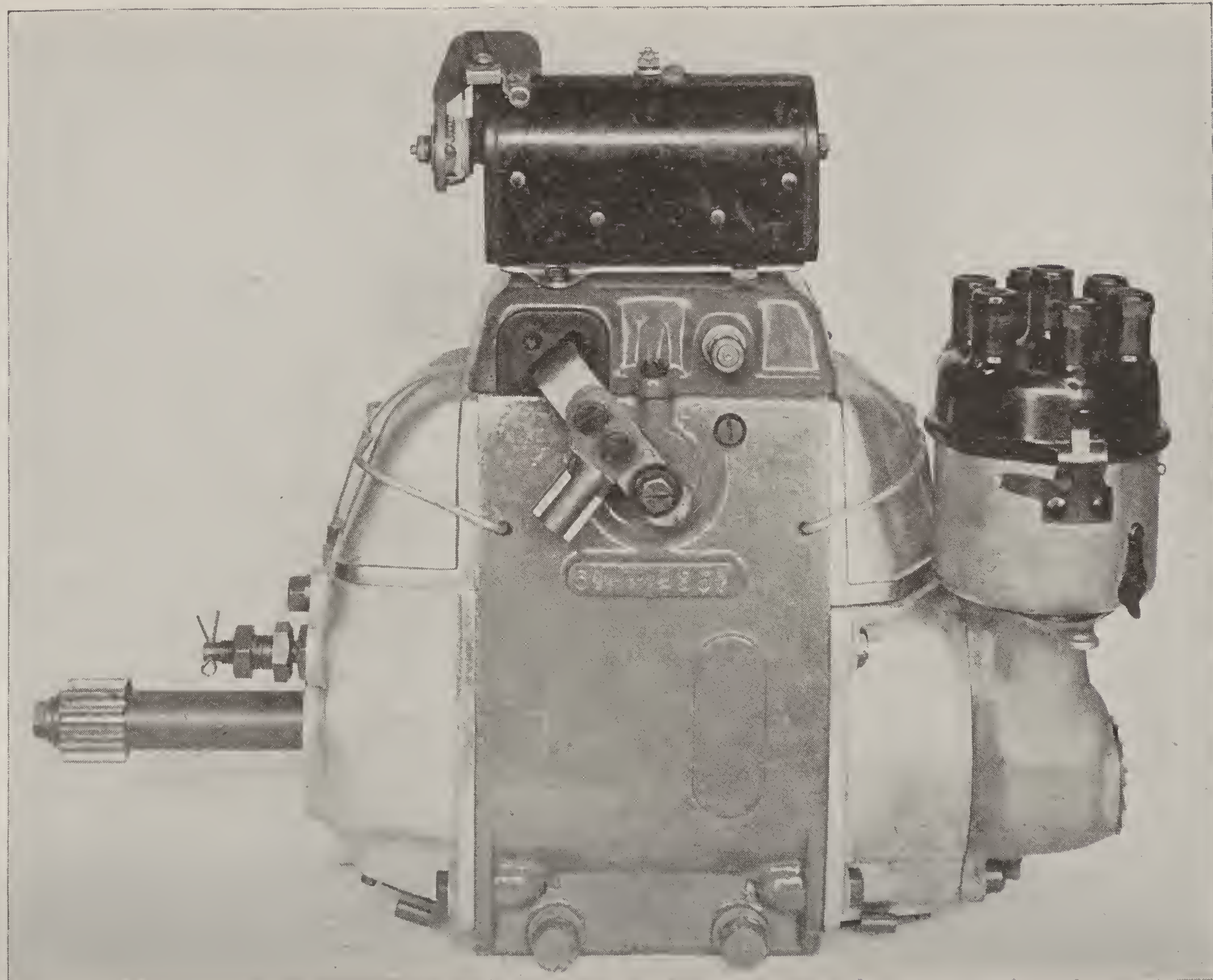
the contacts A when the relay is demagnetized, due to the voltage of the battery exceeding that of the generator.

Trouble in the regulator and cut-out will manifest itself in two ways—insufficient charging current or no charging current reaching the battery and too much current at the higher car speeds. It may be due to several causes, acting either separately or collectively—the armatures springs may be out of adjustment; the current or voltage windings may be short-circuited, open, or grounded; the two sets of contacts may be dirty; or the resistance unit may be open. If the ammeter reading fluctuates though the engine speed remains constant, it is an indication of dirty contacts. They should be trued up with a file. If the regulator has failed, the current may have attained a value of 30 to 40 amperes and caused the contacts to fuse together. Separate and file clean.

NORTH EAST MODEL "G" STARTER-GENERATOR MOUNTED ON DODGE CARS



U-S-L-MOTOR-GENERATOR DISASSEMBLED WITH INSTRUMENT BOARD ABOVE
Courtesy of U. S. Light and Heat Corporation, Niagara Falls, New York



MOTOR-GENERATOR USED ON DELCO STARTING AND LIGHTING SYSTEM

Courtesy of The Dayton Engineering Laboratories Company, Dayton, Ohio

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART VI

ELECTRIC STARTING AND LIGHTING SYSTEMS—(Continued)

PRACTICAL ANALYSIS OF TYPES—(Continued)

LEECE-NEVILLE SYSTEM

Six-Volt; Two-Unit; Two-Wire

Generator. Standard shunt-wound bipolar type, combined with ignition timer and distributor driven by a worm gear on the armature shaft. The generator is mounted on the left side of the engine and is driven by the pump shaft (Haynes 1913 installation, and subsequent models to date).

It differs from the standard shunt-wound machine in that the shunt field is connected to the regulating third brush. This brush collects current from the commutator and excites the field, so that a strong shunt field is provided at comparatively low speeds. As the speed increases, the voltage supplied to the shunt field decreases, even though the total voltage between the main brushes may have increased. This weakens the field and prevents the output of the generator from increasing with the increased speed. At higher speeds it acts somewhat similarly to a bucking-coil winding in that it further weakens the field and causes the generator output to decrease still more. The closer the third brush is set to the main brush just above, the greater will be the output of the machine; moving it away from the main brush decreases the output.

Regulation. Generators of the 1915 and 1916 models are controlled by armature reaction through a third brush, the field coils receiving their exciting current from the armature through this brush. The position of the latter on the commutator is shown at *B*, Fig. 293. A slight rotation of this brush relative to the com-

mutator changes the electrical output of the machine. As adjusted at the factory this brush is set to give a maximum output of 15 amperes at $7\frac{1}{2}$ volts. (All generators for 6-volt systems are wound to produce an e.m.f. of $7\frac{1}{2}$ volts, or thereabout, in order that the voltage of the generator may exceed that of the battery when the latter is fully charged. The e.m.f. of generators for 12-volt and 24-volt systems also exceeds that of their batteries in about the same proportion. Otherwise, the generator would not be able to force current through the battery.)

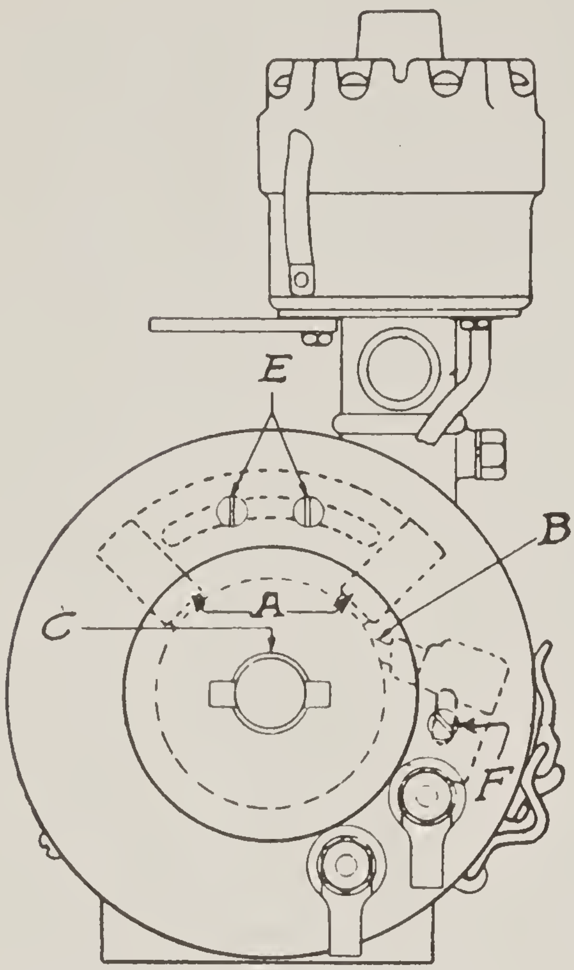


Fig. 293. Diagram of Arrangement of Brushes on Leece-Neville 6-Volt Generator

Starting Motor. The motor is of the bipolar series-wound type driving the engine through a roller chain and an over-running clutch.

Instruments. An indicating type of battery cut-out is employed, thus combining the functions of the cut-out and ammeter in one device. The details of this device are shown in Fig. 294. *O* is the winding or coil of the electromagnet of which the U-shaped bar 8 forms the magnetic circuit. At *4* is the pivoted armature, normally held in the *OFF* position as shown by a spring, when no current is passing, and adapted to be drawn against the pole pieces of the magnet when the latter is excited by the charging current. As the two-wire system is employed, the cut-out breaks both sides of the battery-charging circuit and it is provided with six current-carrying contacts on each of the sides of the circuit. Four of these, which carry most of the current, are *copper* to bronze,

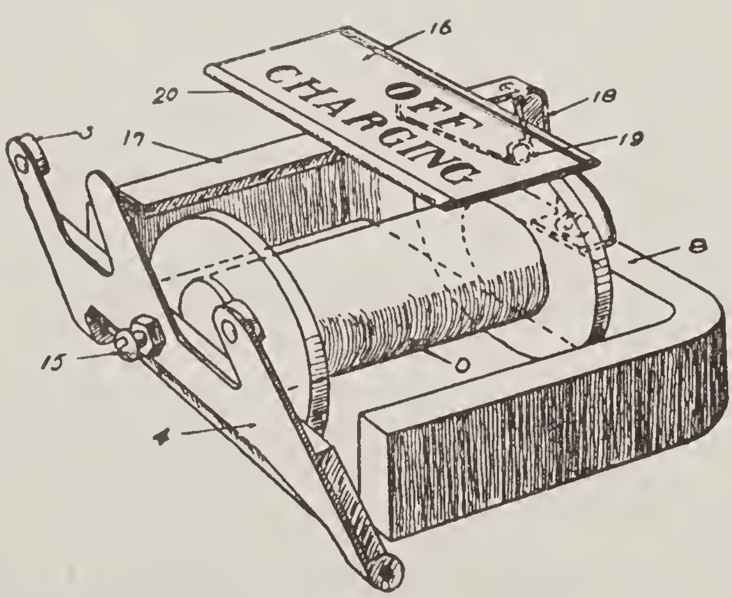


Fig. 294. Details of Leece-Neville Indicator

while those that take the spark in breaking the circuit are *cophite* to iron and are actuated by a spring. The indicating target *16* is held in the *OFF* position by the spring *19* when no current is passing, and this reading appears in the opening of the panel on the cover. When the generator starts and the cut-out closes, the target is moved to bring the word *CHARGING* in the opening. The same panel also carries the three-way lighting switch controlled by buttons. The central button closes the circuit to the headlights and tail lights in the usual manner, while the upper button throws the headlights in series-parallel connection. As this doubles the resistance, it halves the voltage passing through the lamps, and they, accordingly, burn dimly. The lower button controls the cowl light over the instruments on the dash.

Wiring Diagram. Fig. 295 illustrates the Haynes 1915 installation. While two wires are employed for connecting all the apparatus, it will be noted that the storage battery and the dry-cell battery are grounded by a common ground connection. This is to permit using current from the storage battery for ignition, the corresponding ground to complete the circuit being noted at the ignition coil, close to the distributor. The connections *G* and *B* on the panel board are those of the generator and the battery to the indicating battery cut-out, the connections of three lighting switches being shown just to the right. In Fig. 296 is shown the Leece-Neville installation in White cars.

Instructions. Never run the engine when the generator is disconnected from the battery unless the generator is short-circuited, as otherwise it will be burned out in a very short time. This applies to all lighting generators except those protected by a fuse in the field circuit, in which case the fuse will be blown. The Leece-Neville generator can be short-circuited by taking a small piece of bare copper wire and connecting the two brush holders together with it. Instructions for short-circuiting other makes are given in connection with the corresponding descriptions.

Later models of the Leece-Neville generator are provided with a circuit-breaker. On the Haynes 12-cylinder models, this is mounted on top of the generator, while in some cases it is combined with the ammeter on the dash. To protect the generator and battery, there is a 5-ampere cartridge fuse under the cover of this circuit-breaker.

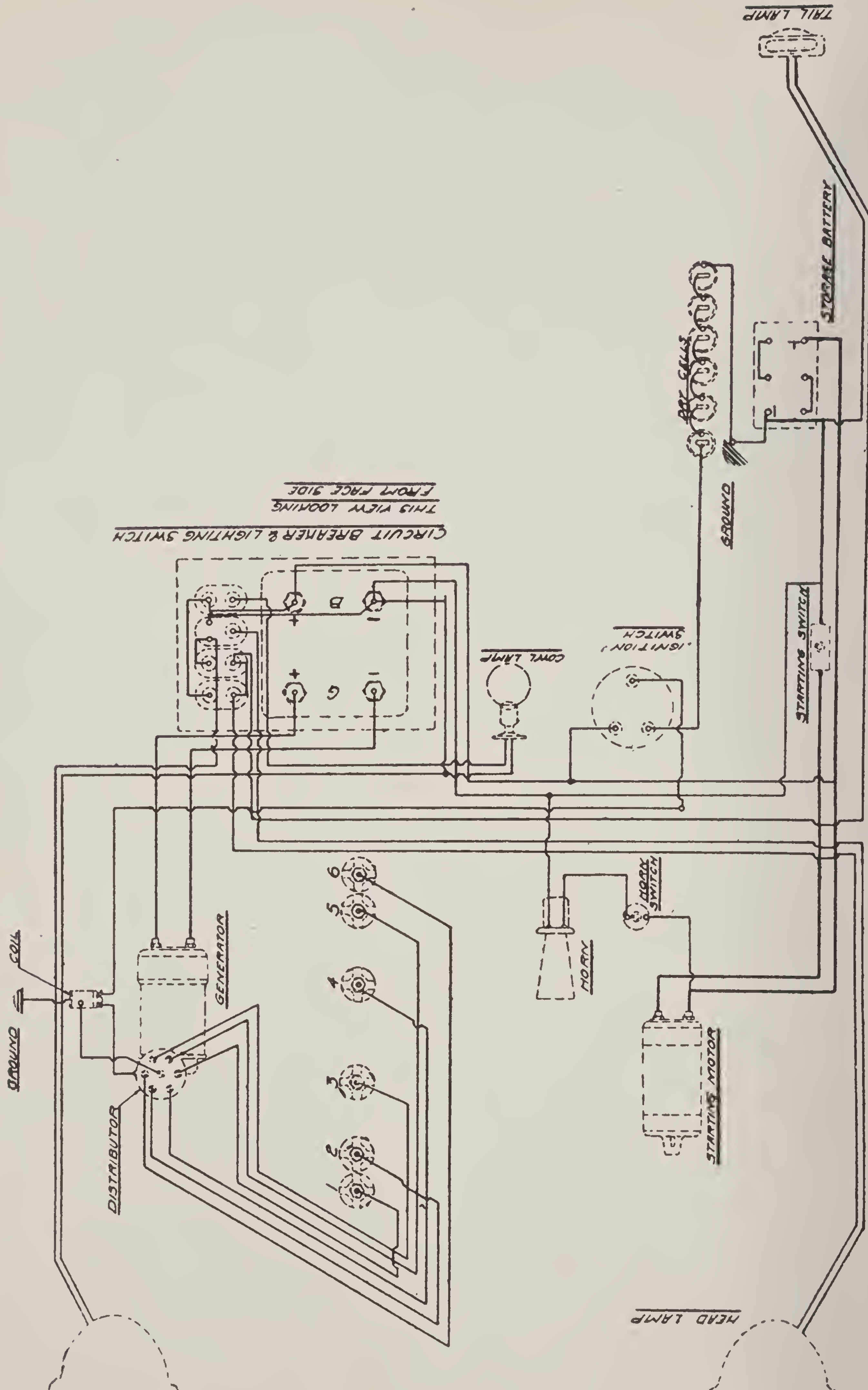


Fig. 295. Wiring Diagram for Leece-Neville System on Haynes Light Six

When this fuse blows out, both the generator and the circuit-breaker become inoperative. Any one of the following conditions may cause

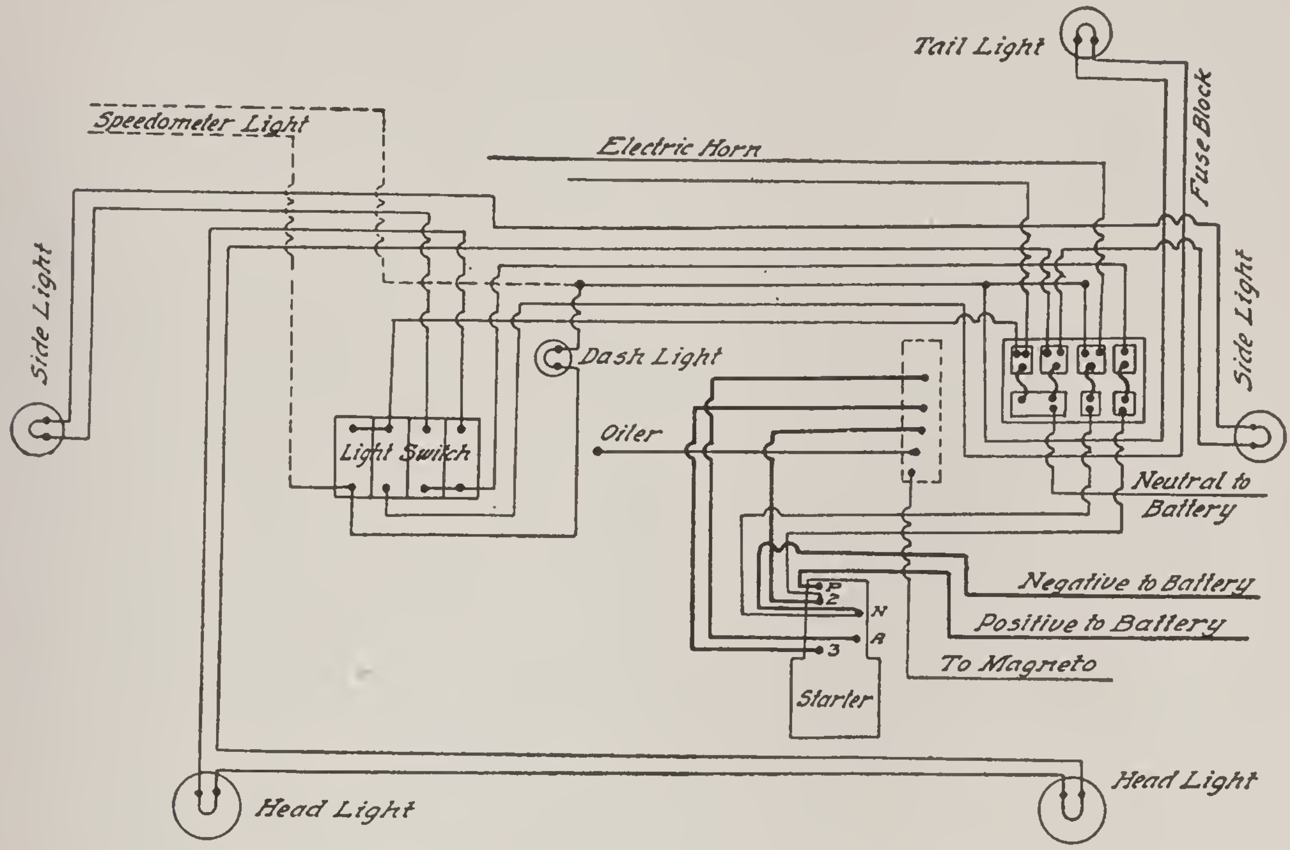


Fig. 296. Wiring Diagram of Leece-Neville System on White Cars

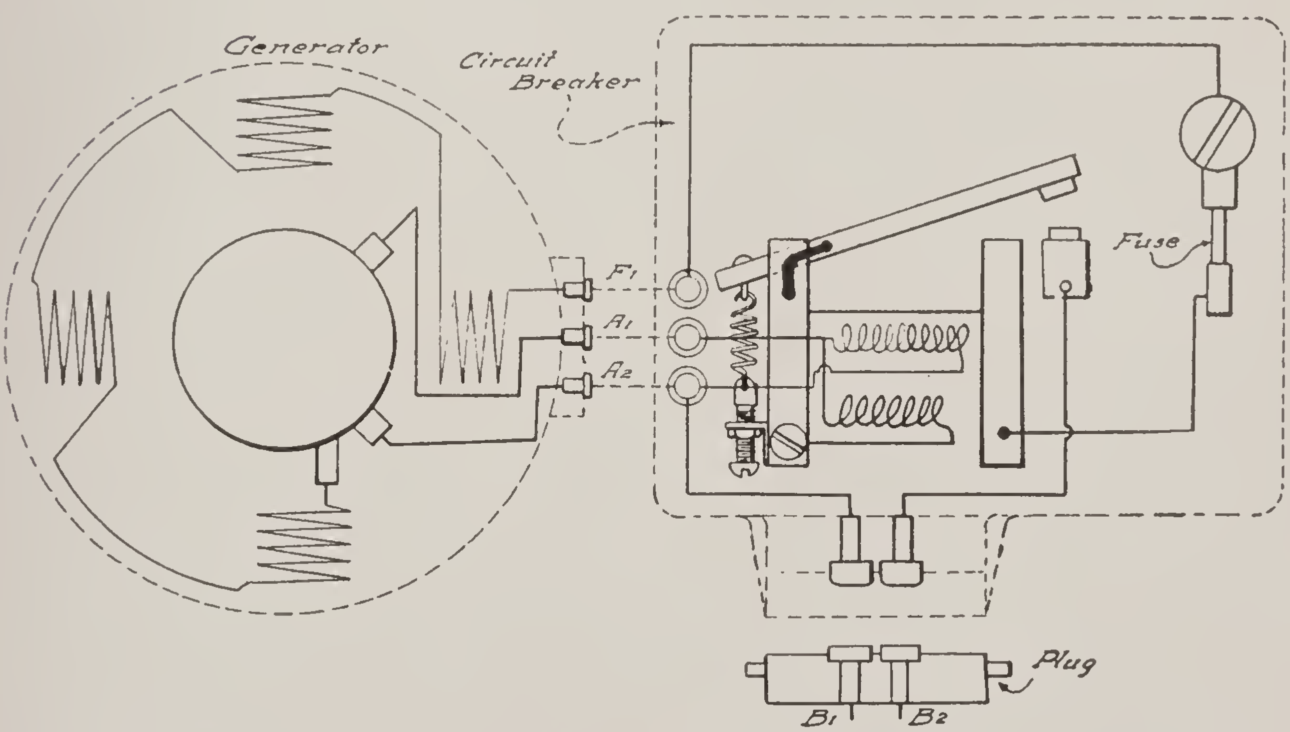


Fig. 297. Wiring Diagram of Generator and Circuit-Breaker Circuits for Leece-Neville System
Courtesy of The Seece-Neville Company, Cleveland, Ohio

this fuse to blow out: loose or corroded connections at the battery; an open circuit in the wiring on the battery side of the cut-out; not sufficient water in the battery; output of the generator too high;

allowing the main brush directly above the third brush to stick in its holder; a loose connection at the point A_2, Fig. 297; improper insulation between the wires B_1 and B_2 in the connector plug, Fig. 297. By an open circuit is meant an actual break at a connector or a terminal, or in the wiring itself, while a loose connection signifies an insecurely fastened terminal or wire, at a junction box, or at any other part of the system. If there is a short-circuit in the field winding of the generator, this also will cause the fuse to blow out.

Testing the Field Winding. While a short-circuit in the field winding of any generator is a rare fault, there are times when the trouble cannot be traced to any other part of the system. To test the Leece-Neville generator for this, connect the negative terminal of the portable testing ammeter to F_1, Fig. 297, while the positive terminal of the motor must be connected to the positive terminal of a 6-volt storage battery; the negative terminal of the battery is to be connected to the third brush when drawn from its holder. If the indication of the ammeter is above 4 amperes, there is a short-circuit in the field windings. In such a case, the generator should be returned to the manufacturers for repairs.

With the engine running, the working of the generator should be inspected from time to time. In case there is excessive sparking or "arcing" between the brushes and the commutator, examine the connections at F_1 and A_1 and see that the screws are perfectly tight, as these screws sometimes work loose and are responsible for this arcing which is destructive to the commutator. The loosening of the connections at F_1 and A_1 will have no effect on the fuse; but if the connection at A_2 loosens, the fuse will burn out. When inspecting the operation of the generator, see that the brushes are making good even contact with the commutator, and wipe away all particles of dust and grit from around the brushes and their holders. With the engine stopped, see that the brushes move freely in their holders. This should always be done where a car has been laid up for some time (before starting the engine) as the brushes, through disuse, will have a tendency to stick.

The fuse in the circuit-breaker has no effect whatever on the output of the generator, so that a larger fuse must not be inserted in case the generator is not delivering its rated output or more. The makers supply a 5-ampere fuse for this purpose, and if a fuse of

heavier capacity is employed, it will cause both the circuit-breaker and the generator so burn out. This will be the case also where a "jumper" is resorted to, i.e., a piece of wire or other metal bridging the fuse clips so that the fuse is cut out of the circuit. It must be borne in mind, however, that these fuses are more or less fragile and are likely to become damaged by careless handling. A fuse whose connections have been loosened up is likely to blow out on that account, so before inserting a fuse in the clips of the circuit, it should be examined to see that the ferrules on each end of the cartridge are perfectly tight. Where a good fuse has been inserted and it blows out, the cause should be ascertained before inserting another fuse.

Regulating Brush. In case the generator output falls off as shown by its inability to keep the battery properly charged, the battery itself and all connections being in good condition, and a proper amount of day running being done to provide the necessary charging current, the trouble may be in the regulating brush of the generator. Test by inserting an ammeter, such as the Weston portable or any other good instrument with a scale reading to 30 amperes, in the line between the generator and the battery. Run the engine at a speed corresponding to 20 miles per hour, at which rate the ammeter should record a current of approximately 15 amperes. If the ammeter needle butts against the controlling pin at the left end of the scale instead of showing a reading, it indicates that the polarity is wrong, and the connections should be reversed. Should there be no current whatever, the needle will stay perfectly stationary except as influenced by vibration. If the ammeter shows a reading of less than 15 amperes, the current output of the generator may be increased by loosening the set screw holding the third brush and rotating the brush slightly in the same direction as the rotation of the armature. This should be done with the generator running and the ammeter in circuit, noting the effect on the reading as the brush is moved. To decrease the output, it should be moved in the opposite direction until the proper reading is obtained, after which the brush must be sanded-in to a good fit on the commutator. It may sometimes occur that sufficient movement cannot be given the third brush without bringing it into contact with one of the main brushes. This must be avoided by loosening the two set screws *E*, Fig. 293, and moving the main brush holder away

from the third brush until there is no danger of their touching. After securing the desired adjustment, fasten the third brush in place again, stop the engine, and then reconnect the generator to the battery. Do not cut the ammeter out of the circuit while the generator is running.

To Adjust Third Brush. Before making any adjustment of the third brush when it is suspected that any trouble with the current supply is due to the generator, the output of the generator should be tested. On a car equipped with lamps totaling 250 candle power or more (this refers to White busses), the generator should produce 20 amperes. Run the engine at a speed sufficient to drive the car 15 o 16 miles per hour on direct drive and note the reading of the dash ammeter. In case the car has seen considerable service, it may be well to check the dash ammeter with the more accurate portable ammeter described in connection with other tests in previous and subsequent sections. Where the car lighting system totals 250 c.p. or over, and the ammeter reading shows more than four amperes above or below 20, the generator should be adjusted to give its rated capacity of 20 amperes—as every 15 c.p. less than 250 c.p. used on the car, lower the output of the generator by one ampere. By making the adjustments in this manner, the storage battery will be amply protected.

Before making any generator adjustments, test the storage battery with the hydrometer. Do not add any distilled water just previous to making this test unless the level of electrolyte is right down to the plates so that sufficient liquid cannot be drawn into the hydrometer; in this case, add water and charge the battery for at least one hour before making the hydrometer test. If the specific gravity of the electrolyte is 1,250 or over, and the generator is found to be delivering less than the rated lamp load, no adjustment of the generator should be made.

To increase the output of the generator, rotate the third brush in the direction of rotation of the armature; to decrease the output, move the brush against the direction of rotation. Adjustments should be made with the engine standing. Loosen the screw at the rear of the commutator housing shown at the point *F*, Fig. 293. This releases the third brush holder, and the brush may then be moved in the direction desired. It should be moved only a short distance,

and the generator then should be tested until the desired output is secured. In case the third brush should come in contact with the main brush above in the course of adjustment, it will be necessary to move the main brushes. To do this, loosen the two set screws *E*, Fig. 293, and move the main brush holder far enough away from the third brush so that there is no possibility of contact between them. When the desired location is found, sand-in the third brush to the commutator and also clean the commutator with a piece of worn sandpaper as described in the section on Sanding-In the Brushes (Delco instructions); if it has been necessary to move the main brushes, they should be sanded-in also. The brush holder screws should be well tightened after making any adjustments to prevent any possibility of the vibration and jolting loosening them up and throwing the generator out of adjustment again.

Brush Replacements. Never replace any of the brushes on either the generator or starting motor with any but those supplied by the manufacturer of the system for this purpose. Motors and generators adapted for use on electric-lighting circuits are usually fitted with plain carbon brushes. These are not suitable for use on automobile generators or starting motors owing to their resistance being much higher. Due to the low voltage of electric apparatus on the automobile, special brushes of carbon combined with soft copper are usually employed. Brushes also differ greatly in hardness, and a harder brush than that for which the commutator is designed will be liable to score it badly besides producing a great deal of carbon dust, which is dangerous to the windings. This, of course, applies to all makes of apparatus and not merely to that under consideration.

Generator or Motor Failure. For failure of the generator or of the starting motor, see instructions under Auto-Lite, Delco, and Gray & Davis, bearing in mind, however, that the system under consideration is of the two-wire type, so that in using the test lamp to locate short-circuits a connection to the frame or ground is not always necessary. The short-circuit may be between two adjacent wires of different circuits. Given properly installed wires and cables, there is less likelihood of short-circuits in the wiring of a two-wire system. Defective lamps will not infrequently prove to be the cause, as, in burning out, a lamp often becomes short-circuited.

NORTH EAST SYSTEM*

Twelve-Volt, Sixteen-Volt, or Twenty-Four-Volt; Single-Unit; Single-Wire or Two-Wire, According to the Installation

Dynamotor. The dynamotor is of the four-pole type, with both windings connected to the same commutator. It is designed for installation either with silent-chain drive—as on the Dodge, Fig. 298, in which case the drive is direct either as a generator or as a motor—or with a special reducing gear and clutch for driving from the pump or magneto shaft of the engine. In the latter type, the starting switch is mounted on the gear housing, which is integral with

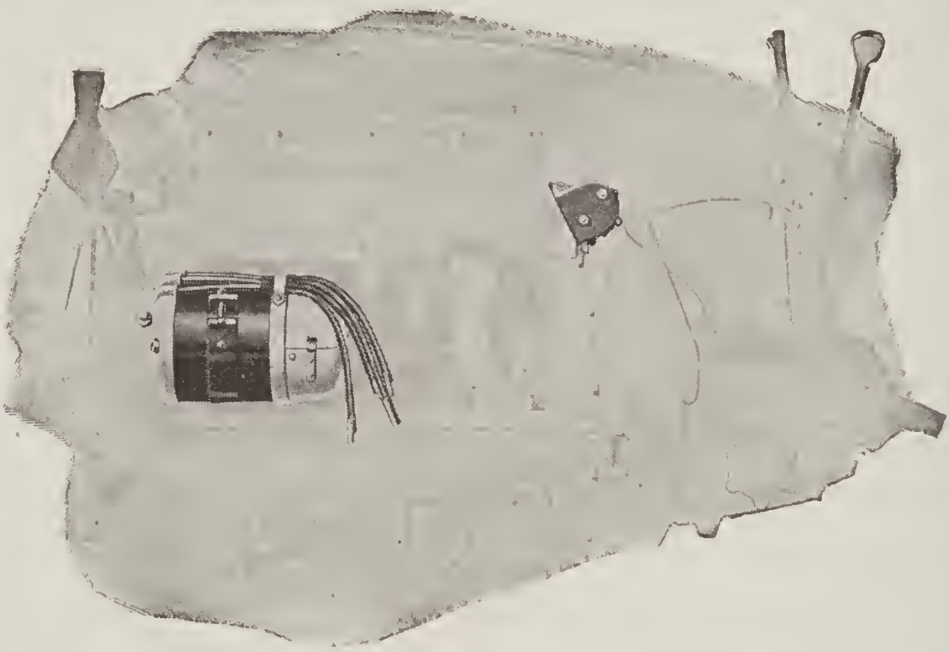


Fig. 298. North East Dynamotor with Silent-Chain Drive. Starting Switch Shown at Right
Courtesy of North East Electric Company, Rochester, New York

the bedplate of the dynamotor. In this case the drive as a generator is $1\frac{1}{2}$ times engine speed, while as a starting motor the reduction through the gear is approximately 40 : 1.

Regulation. The regulation is by means of a differential winding or bucking coil, in connection with an external resistance automatically cut into the shunt-field circuit by a relay in series with the battery cut-out. See "limiting relay", Fig. 299. The "master relay" is the battery cut-out, and the condenser is to reduce sparking at the contacts of these relays.

Protective Devices. There is a fuse in the field circuit of the generator, but fuses are not employed on the lighting circuits.

*The voltage of any system may be determined by counting the number of cells in the storage battery, and multiplying by 2 in the case of a lead battery, or multiplying by $1\frac{1}{4}$ where an Edison battery is used.

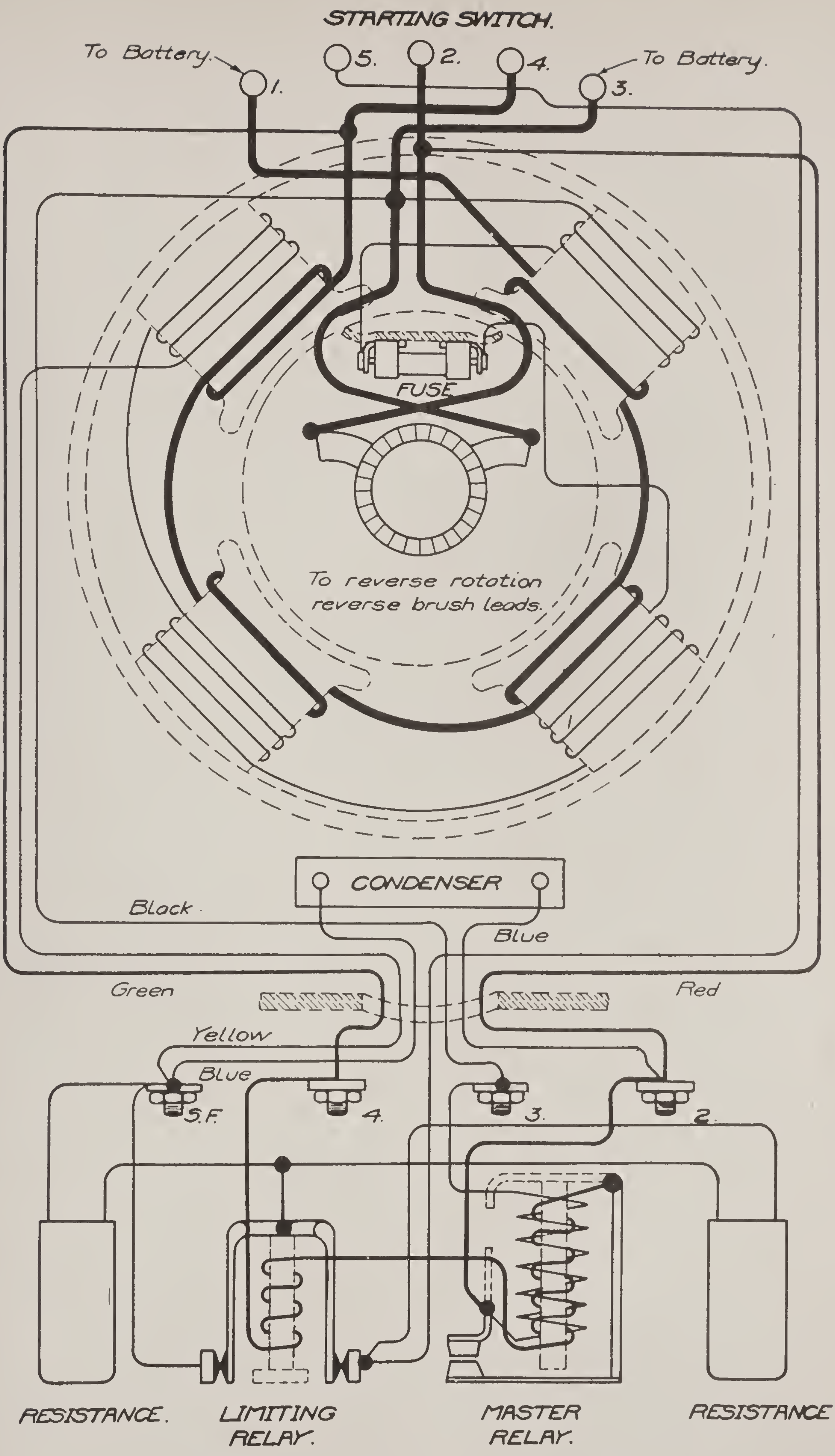


Fig. 299. Diagrammatic Section of North East Dynamotor, Showing Regulator (Limiting Relay) and Cut-Out (Master Relay)

Wiring Diagrams. A graphic diagram of the North East

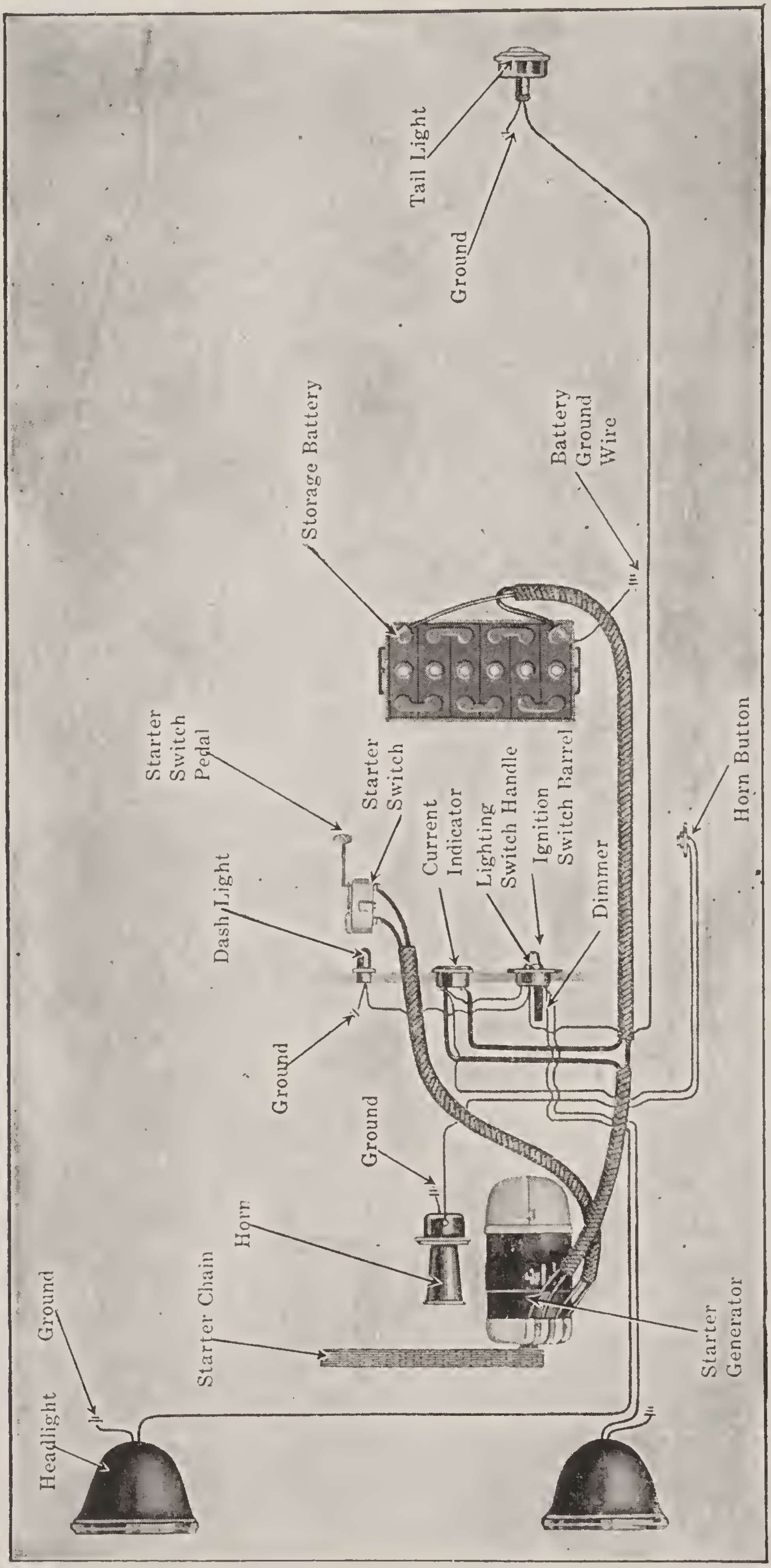


Fig. 300. Diagrammatic Layout of North East Installation on Dodge Cars
Courtesy of North East Electric Company, Rochester, New York

installation on the Dodge is shown in Fig. 300. This is a 6-cell or 12-volt system single-wire type. The sprocket on the forward end

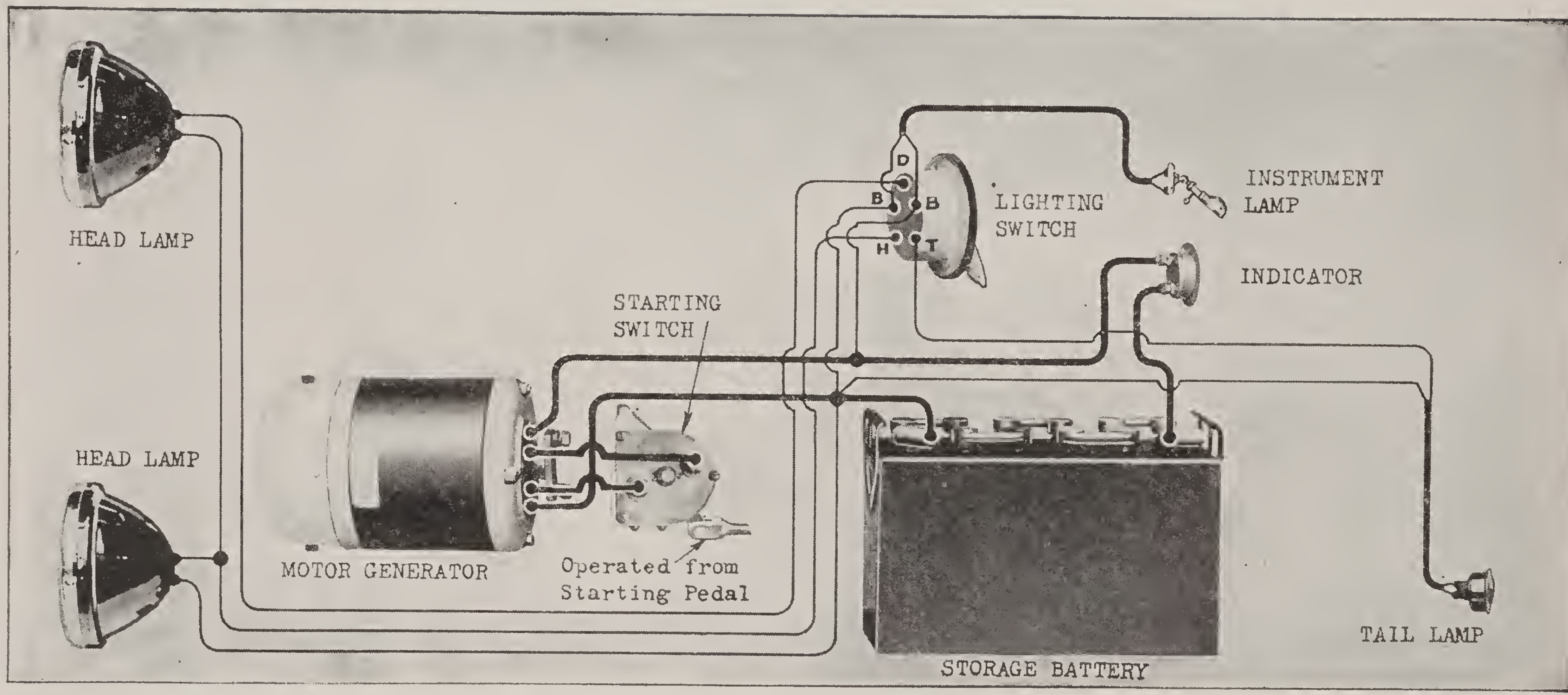


Fig. 301. Diagrammatic Layout of North East 12-Volt Installation on Krit 1915 Automobiles (14-Volt Lamps)

of the machine drives from a similar but much larger sprocket on the forward end of the crankshaft of the engine through a silent chain. The wiring diagram of the Krit 1915, Fig. 301, will be recognized as being the same as the Dodge, except for the use of two wires throughout. Fig. 302 shows the wiring diagram of an 8-cell or 16-volt system, but the battery is divided for the lighting circuits so that $8\frac{1}{2}$—9-volt lamps are used, whereas 14-volt bulbs are necessary on the Dodge installation as the entire battery is used in series for lighting. The wiring of the 12-cell or 24-volt system is shown in Fig. 303. In this case the battery is divided for lighting so that 7-volt lamps are employed. Such a system is usually designated as 24—6-volt, while the previous one would be a 16—8-volt. The North East installation for Ford cars is 24—14-volt. With the exception of the Dodge, the two-wire system is employed on the installations mentioned.

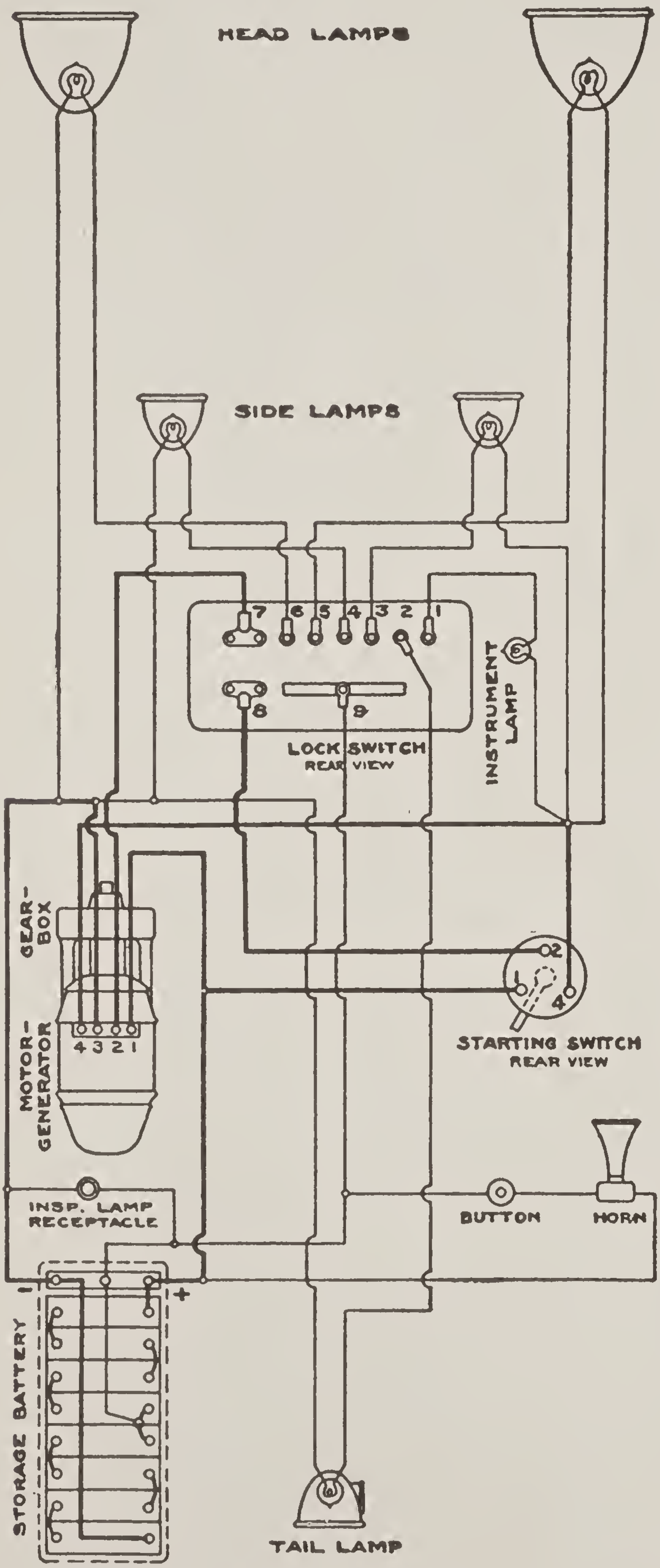


Fig. 302. Wiring Diagram for 16-Volt North East System Using 8½—9-Volt Lamps

Instructions. The indicator shows when the battery is charging or discharging and accordingly should indicate OFF when

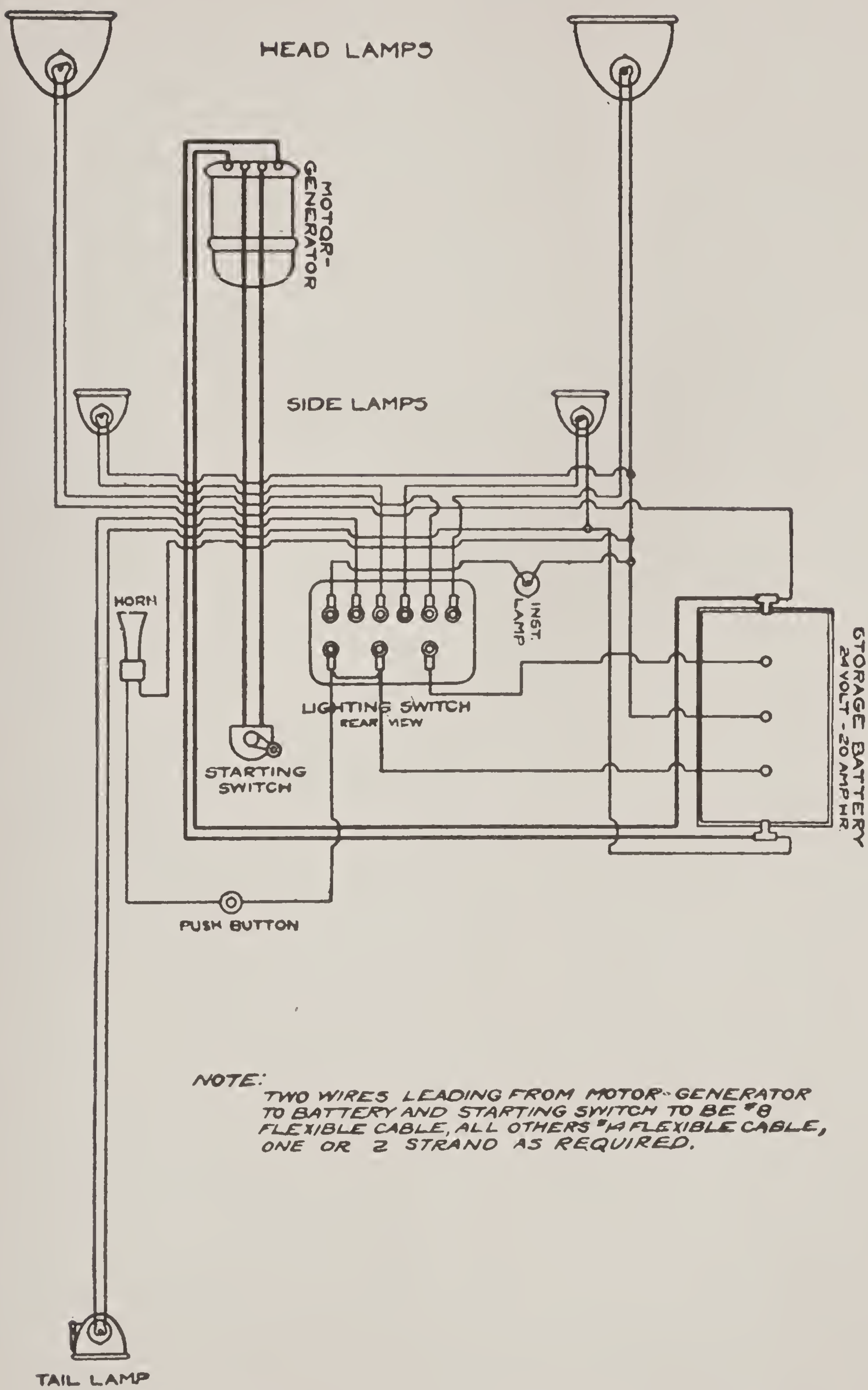


Fig. 303. Wiring Diagram for 24-Volt North East System Using 7-Volt Lamps

the engine is idle and no lamps are lighted. A discharge reading under such conditions would indicate the presence of a ground, short-circuit, or failure of the battery cut-out to release. Should the generator fail to charge the battery, note whether the field fuse has been blown by short-circuiting the fuse clips with the pliers or a piece of wire while the engine is running at a moderate speed. Look for cause of failure before replacing the fuse. If the fuse has not blown, see whether battery cut-out is operating; look for loose connections at generator, cut-out, and battery. If the battery is properly charged, loose connections are also most likely to be the cause of failure of the starting motor; or, any of the instructions covering brushes, commutator, etc., as given previously, may apply.

Battery Cut-Out and Regulator (*Relays*). In every case where it is necessary to make repairs on starter-generators equipped with the earlier type cut-out and regulator (relays), 1283 (12-volt), 1860 (16-volt), 2501 (24-volt), 1900 (16-volt), and 2503 (12 and 24-volt), it is advisable to replace the cut-out entirely, installing a later and improved type, 1196 (12-volt), or 1197 (24-volt and 16-volt). In order to adapt the starter-generator to the 1196 and 1197 cut-out, or relay units, it is necessary to cut out the bosses on the commutator end bearing in which the studs holding the original relay were screwed. This will provide the clearance required to prevent grounding of the nuts which secure the units to their baseboard. As a further precaution against grounding, it will be necessary to cut away that portion of the gasket retainer which would be liable to come into contact with the armature of the master relay.

Fasten down the baseboard which carries the relays by screwing the resistance unit studs into the holes which were used for the former resistance studs. Before making connections on the relay, draw tight all leads which come from inside the starter-generator so as to take up whatever slack they have; then tie them together with string to prevent their slipping back. No loose wire must be left inside the starter-generator, because of its tendency to be drawn in between the armature and the pole pieces. The connections on the four-terminal type starter-generator are made as follows:

Looking at the starter-generator from the driving sprocket end, the main terminals 1, 2, 4, and 3 of the starter-generator are considered as being numbered in anti-clockwise rotation, Fig. 304. Viewing

the relay unit as mounted on the starter-generator with the larger, or master relay, at the left, the four binding posts *a*, *b*, *c*, and *d* are designated from left to right in the same illustration. To relay binding post *a*, connect lead (red) coming from starter-generator terminal 2. To relay binding post *b*, connect lead (black) coming direct from starter-generator terminal 3. To relay binding post *c*, connect lead (green) from starter-generator terminal 4. To relay binding post *d*, connect lead (yellow) from starter-generator shunt-field coils. It is always advisable to check the identity of the leads by inspection and test.

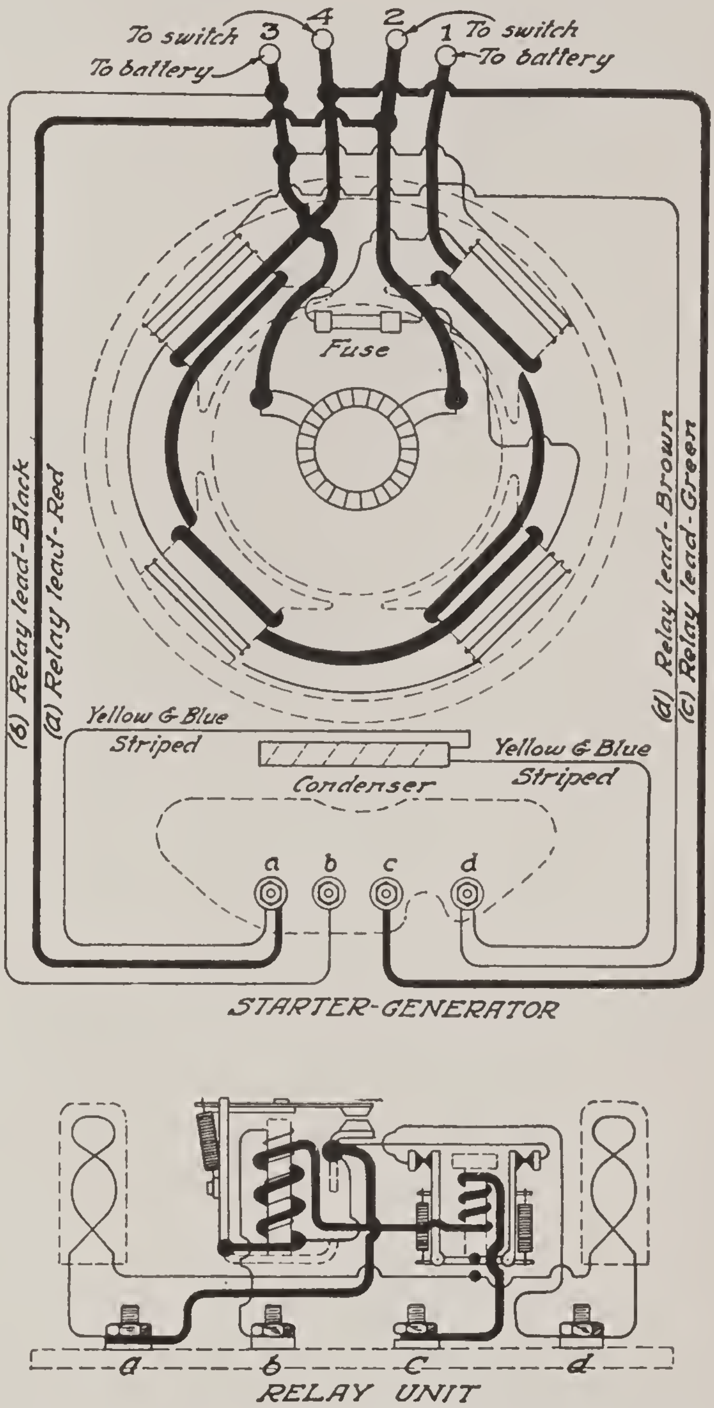


Fig. 304. Internal Wiring Diagram for North East Model "B" Starter-Generator

In order to make a positive distinction between the *d* lead and the *b* lead, both of which are in electrical connection with the starter-generator terminal 3, the following test should be made: Using the test-lamp outfit, send current from starter-generator terminal 3, through each of these wires in turn, and note appearance of the lamp. When the direct lead (*b* lead) is in circuit, the lamp will burn with full brilliance, but when the *d* lead, which includes the starter-generator shunt-field coils, is in circuit, the lamp will be noticeably dimmer.

Five-Terminal Type Unit. The connections on the five-terminal type generator-starter unit are made as follows: Looking at the starter-generator, Fig. 305, from the driving sprocket end, the main terminals 1, 5, 2, 4, and 3, respectively, of the unit are numbered in anti-clockwise rotation (to the left). Viewing the relay unit as

mounted on the starter-generator with the master relay at the left, the four binding posts *a*, *b*, *c*, and *d* are designated from left to right as shown in the illustration. Proceed with the instructions as given for the four-terminal type starter-generator as given. The new type relays 1196 and 1197 are regularly furnished with local connections, as shown in Fig. 304, but it will be necessary to make the following alterations when applied to the five-terminal type starter-generator, so that the relay connections will conform to the diagram in Fig. 305. Remove the jumper lead that connects the frame of the master relay to the rear contact terminal on the limiting relay; remove from relay binding post *a* the left-hand resistance-unit lead. Lengthen this lead by splicing a piece of the same kind of wire to it, and solder it to the limiting relay contact terminal, from which the jumper has been removed. To this terminal must also be soldered the lead coming from starter-generator terminal 5. (In some starter-generators this lead includes the field fuse.)

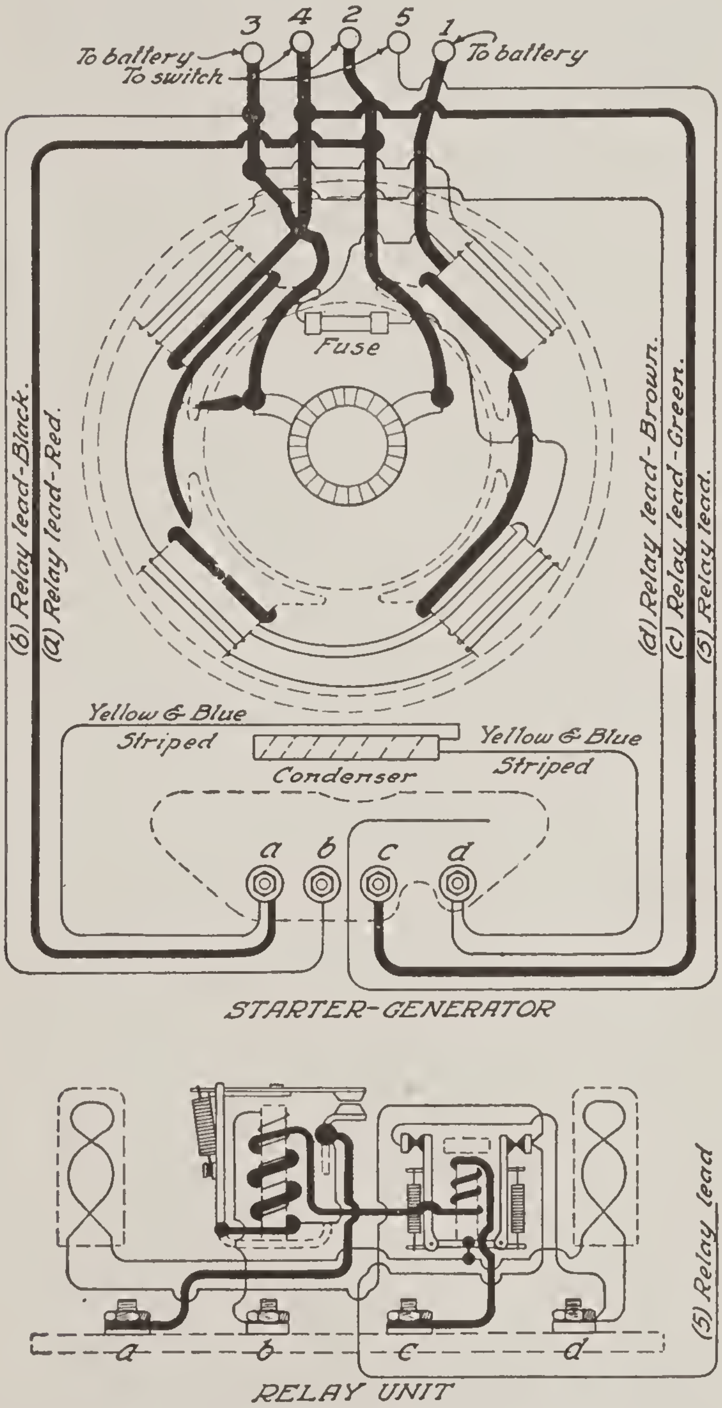


Fig. 305. Internal Wiring Diagram for Model "D" and Model "F" Starter-Generators

The condenser in the early models is mounted between the field coils. One condenser lead must either be connected to the relay binding post *a* as shown in either Fig. 304 or Fig. 305 or be spliced to the wire leading to it. The other condenser lead must either be connected to the relay binding post *d* or spliced to the shunt-field wire leading to it.

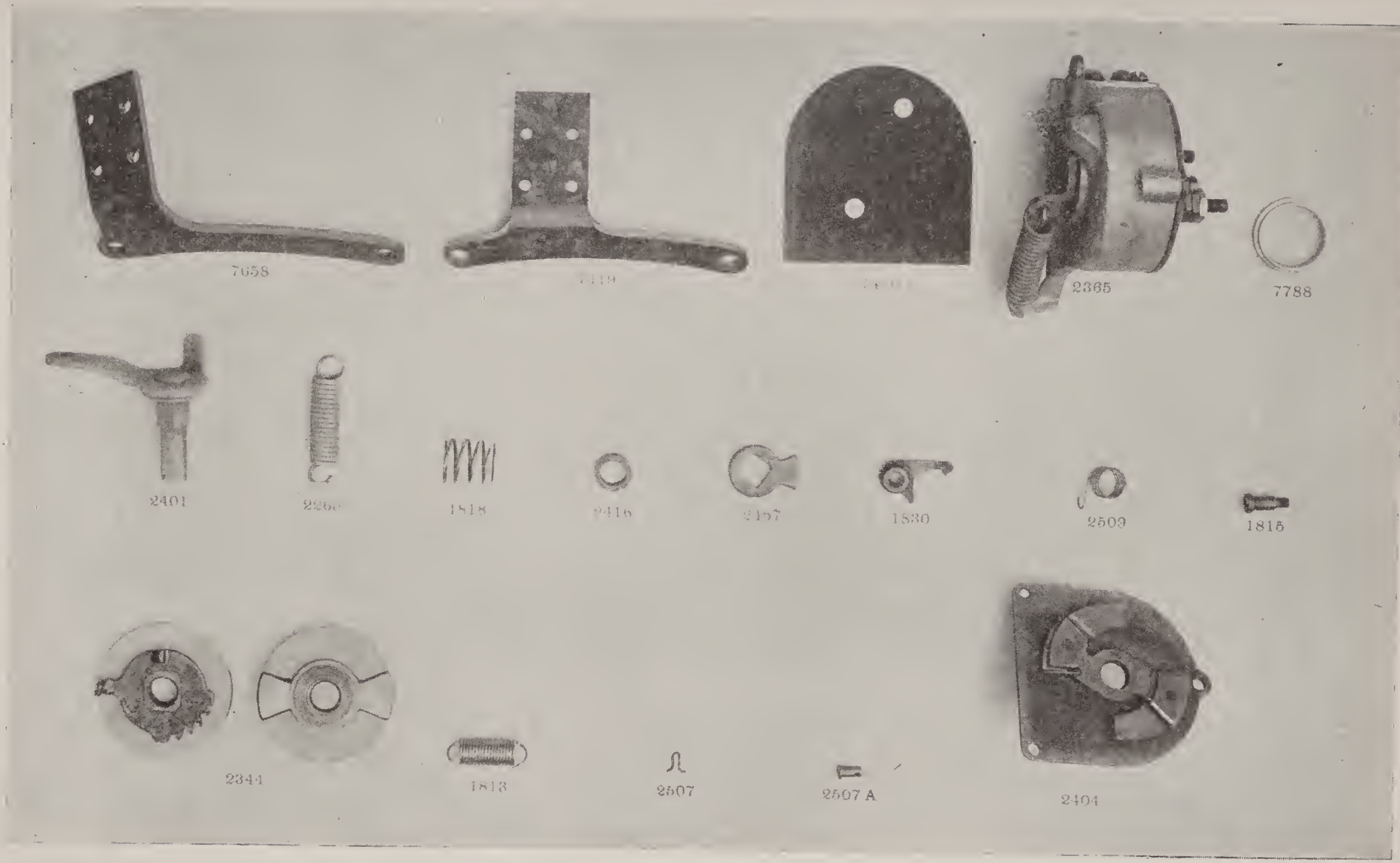


Fig. 306. View of Essential Parts of North East Starting Switch
Courtesy of North East Electric Company, Rochester, New York

Starting Switch. When its operation indicates that the contactor blades have worn, the starting switch should be dismounted, and, if necessary, new blades should be inserted. To disassemble the switch, proceed as follows: (1) Remove the spring 2265, Fig. 306, on the switch case 2365; (2) remove the cotter pin from the collar 2416; (3) withdraw the shaft and lever 2401, together with the spring 1818; (4) remove the three screws which hold the cover 2404 in place, and remove the cover; (5) remove the stop 2457; and (6) disconnect the spring 1813 from the arm of the ratchet and remove the contactor member 2344.

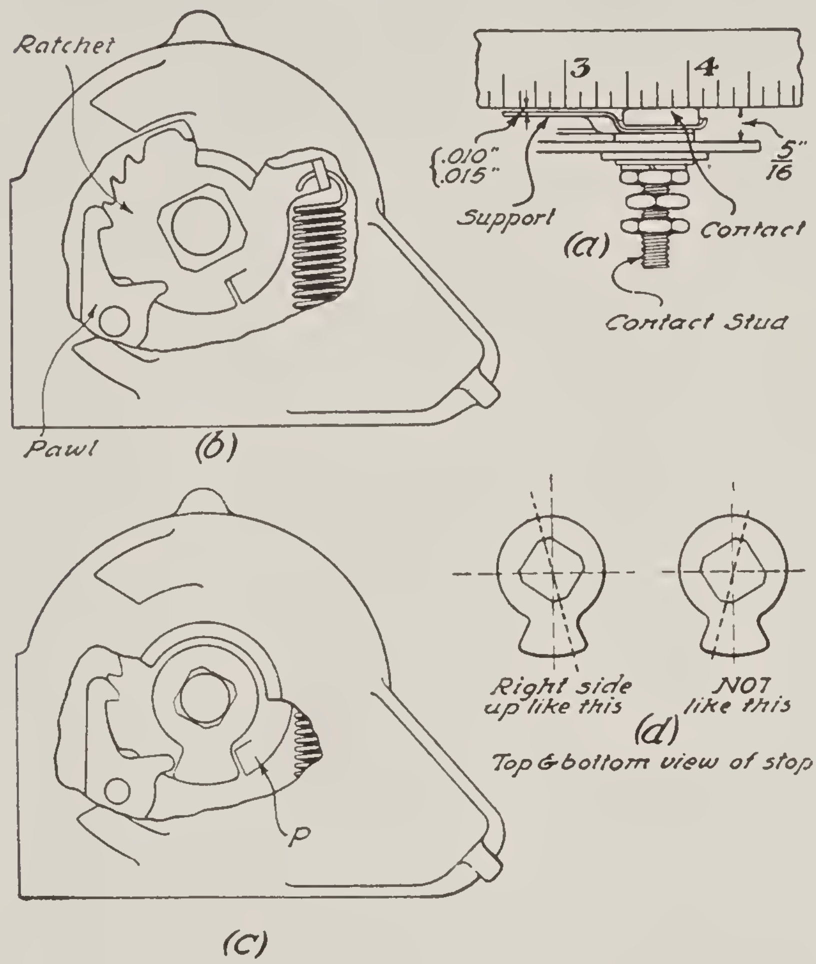


Fig. 307. Assembly of Starting Switch
Courtesy of North East Electric Company, Rochester, New York

If, upon inspection, the contacts are found to be in such a condition that their renewal is necessary, make a replacement of the entire cover member 2404 and the entire contactor 2344. Before placing these new parts in the switch, the following points should receive careful attention: the front edges of the contact blocks should be slightly rounded so as to eliminate the possibility of these edges catching on each other when the switch is being operated. The supports on the cover must be adjusted so that they lie parallel with the faces of the contact blocks.

The upper surfaces of the supports must be .010 to .015 inch lower than the contact surface of the block. Care should be taken that the upper surface of the contact blocks are $\frac{5}{16}$ inch above the inner surface of the cover. A small steel straightedge laid upon the face of the contact block and extended over the supports, as shown in Fig. 307 (*a*), will serve as a means of checking these dimensions.

Before placing in service, the contact surfaces must be carefully cleaned and lubricated with a very small quantity of vaseline. To reassemble the switch: (1) Connect the spring 1813, Fig. 306, to the arm of the ratchet; (2) place the contactor member 2344 in the switch case in such a position that the ratchet will lie against the pawl 1830; and (3) hold the switch case in the left hand, lever side up, and insert the right forefinger through the hole in the switch case and introduce the pawl into the first notch of the ratchet, Fig. 307 (*b*); (4) hold these parts carefully in position and replace the cover 2404, Fig. 306, fastening it to the switch case by means of the three screws; (5) insert the stop through the hole in the switch case and replace it upon the ratchet plate in such a position that the elongated portion of the stop will lie between the raised projection which is found on the ratchet plate and the end of the short lever on the pawl as shown in Fig. 307 (*c*). It is very important that the stop be placed in the switch right side up, Fig. 307 (*d*) illustrating the proper method of doing this. (6) Place the spring on the shaft and replace the shaft in the switch, taking care while entering the shaft not to disturb the arrangement of any of the switch parts; (7) replace the collar and the cotter pin; and (8) connect the spring 2265 with the lug on the switch case. A drop of light oil should be applied to the bearing point at each end of the switch shaft 2401.

Switch Tests. To determine whether the switch has been assembled correctly, pull the lever through the full length of its stroke and allow it to return slowly to its initial position. If the switch is properly assembled, three distinct clicks will be heard while the lever is being moved through its stroke, and a snap will occur just before the lever comes back to its initial position. The switch should be tested electrically, as follows:

Ground Test. Using the lamp-test set as shown in Fig. 263 and following Part V, hold one contact point on the switch case and then connect the other to the two contact studs. The test lamp will not light unless there is a ground.

Operation Test. Hold one of the test points in contact with each of the two studs, and turn the lever through its stroke. If the switch is in proper working condition, the test lamp will light up just after the first click of the switch and continue to burn until the final snap occurs.

TABLE V

Gray & Davis Test Outfit

Mechanical Characteristics								Approximate Electrical Characteristics							
										Master Relay			Lim. Rl	Resis. Unit	
Shown on Plate	Model	Drg. No.	Volts	Rotation	Arm. Dia. (in.)	Style Coupling	Style Terminals	Charge Rate Amp.	Torque Ft.-Lb. @ Amp.	Cuts in Pos. Amp.	Cuts Out Neg. A.	Air Gap (in.)	Air Gap (in.)	No. of Spools	Total Resis.
118, 127	A	1000	16	C.C.	$3\frac{1}{4}$	Shaft.........	4 Post...	7	12 46	3 to 4 @ 1000 r.p.m.	0	.030	.025	1	14 ω
118, 127	A	2000	16	C.	$3\frac{1}{4}$	Shaft.........	4 Post...	7	12 46	3 to 4 @ 1000 r.p.m.	0	.030	.025	1	14 ω
	A-4	1070	16	C.	$3\frac{1}{4}$	Oldham......	5 Lead...	7	12 46	3 to 4 @ 1000 r.p.m.	0	.030	.025	1	14 ω
	A-4	1080	16	C.C.	$3\frac{1}{4}$	Oldham......	5 Lead...	7	12 46	3 to 4 @ 1000 r.p.m.	0	.030	.025	1	14 ω
123	B-1	1102	16	C.	$3\frac{3}{4}$	Oldham......	5 Post...	6	22 90	3 to 4 @ 1000 r.p.m.	0	.030	.025	1	19 ω
123	B-1	1103	16	C.C.	$3\frac{3}{4}$	Oldham......	5 Post...	6	22 90	3 to 4 @ 1000 r.p.m.	0	.030	.025	1	19 ω
123	B-2	1106	24	C.	$3\frac{3}{4}$	Oldham......	5 Post...	6	36 150	3 to 4 @ 1250 r.p.m.	−1	.030	.025	2	28 ω
123	B-2	1109	24	C.C.	$3\frac{3}{4}$	Oldham......	5 Post...	6	36 150	3 to 4 @ 1250 r.p.m.	−1	.030	.025	2	28 ω
126	F-1	1210	24	C.	$3\frac{3}{4}$	Sprocket.....	4 Post...	4	36 150	3 to 4 @ 1250 r.p.m.	−1	.030	.025	2	28 ω
125	D-1	1220	24	C.	$3\frac{3}{4}$	Oldham......	4 Post...	4	36 150	3 to 4 @ 1250 r.p.m.	−1	.030	.025	2	28 ω
125	D-1	1221	24	C.C.	$3\frac{3}{4}$	Oldham......	4 Post...	4	36 150	3 to 4 @ 1250 r.p.m.	−1	.030	.025	2	28 ω
124	D-6	1223	24	C.	$3\frac{3}{4}$	Flange.......	4 Post...	5	36 150	3 to 4 @ 1250 r.p.m.	−1	.030	.025	2	28 ω
124	D-6	1224	24	C.C.	$3\frac{3}{4}$	Flange.......	4 Post...	5	36 150	3 to 4 @ 1250 r.p.m.	−1	.030	.025	2	28 ω
123	B-3	1246	12	C.	4	Oldham......	5 Post...	7	35 210	3 to 4 @ 1000 r.p.m.	0	.030	.025	2	19 ω
123	B-3	1247	12	C.C.	4	Oldham......	5 Post...	7	35 210	3 to 4 @ 1000 r.p.m.	0	.030	.025	2	19 ω
123		1248	12	C.	$3\frac{3}{4}$	Oldham......	5 Post...	7	32 200	3 to 4 @ 1000 r.p.m.	0	.030	.025	2	19 ω
123		1249	12	C.C.	$3\frac{3}{4}$	Oldham......	5 Post...	7	32 200	3 to 4 @ 1000 r.p.m.	0	.030	.025	2	19 ω
125	D-2	1250	12	C.	4	Oldham......	4 Post...	7	35 210	3 to 4 @ 1000 r.p.m.	0	.030	.025	2	19 ω
125	D-2	1251	12	C.C.	4	Oldham......	4 Post...	7	35 210	3 to 4 @ 1000 r.p.m.	0	.030	.025	2	19 ω
126, 126-A	F-2	1252	12	C.	4	Sprocket.....	4 Post...	7	35 210	3 to 4 @ 1000 r.p.m.	0	.030	.025	2	19 ω
							4 Lead...								
126	F-2	1253	12	C.C.	4	Sprocket.....	4 Post...	7	35 210	3 to 4 @ 1000 r.p.m.	0	.030	.025	2	19 ω
126-A							4 Lead...								
124	D-7	1254	12	C.	4	Flange.......	4 Post...	7	35 210	3 to 4 @ 1000 r.p.m.	0	.030	.025	2	19 ω
124	D-7	1255	12	C.C.	4	Flange.......	4 Post...	7	35 210	3 to 4 @ 1000 r.p.m.	0	.030	.025	2	19 ω
125	D-2	1256	12	C.	$3\frac{3}{4}$	Oldham......	4 Post...	7	32 200	3 to 4 @ 1000 r.p.m.	0	.030	.025	2	19 ω

TABLE V—(Continued)

Gray & Davis Test Outfit

Mechanical Characteristics								Approximate Electrical Characteristics							
										Master Relay			Lim.Rl	Resis. Unit	
Shown on Plate	Model	Drg. No.	Volts	Rotation	Arm. Dia. (in.)	Style Coupling	Style Terminals	Charge Rate Amp.	Torque Ft.-Lb. @ Amp.	Cuts in Pos. Amp.	Cuts Out Neg.A.	Air Gap (in.)	Air Gap (in.)	No. of Spools	Total Resis.
125	D-2	1257	12	C.C.	$3\frac{3}{4}$	Oldham......	4 Post...	7	32 200	3 to 4 @ 1000 r.p.m.	0	.030	.025	2	19 ω
126		1258	12	C.	$3\frac{3}{4}$	Sprocket.....	4 Post...	7	32 200	3 to 4 @ 1000 r.p.m.	0	.030	.025	2	19 ω
126-A							4 Lead...								
126		1259	12	C.C.	$3\frac{3}{4}$	Sprocket.....	4 Post...	7	32 200	3 to 4 @ 1000 r.p.m.	0	.030	.025	2	19 ω
126-A							4 Lead...								
80-A	D-9	1264	12	C.	4	Sprocket.....	4 Lead...	6.5	35 210	3 to 4 @ 1000 r.p.m.	0	.030	.025	2	19 ω
80-A	D-9	3520	12	C.C.	4	Sprocket.....	4 Lead...	7	35 210	3 to 4 @ 1000 r.p.m.	0	.030	.025	2	19 ω
126	F-3	3500	24	C.	4	Sprocket.....	4 Post...	6	55 200	3 to 4 @ 1250 r.p.m.	—1	.030	.025	2	28 ω
126-A							4 Lead...								
126	F-3	3500Fj	24	C.	4	Sprocket......	4 Post...	4	55 200	3 to 4 @ 1250 r.p.m.	—1	.030	.025	2	28 ω
126-A							4 Lead...								
126		3502	24	C.	4	Sprocket......	4 Post...	6	55 200	3 to 4 @ 1250 r.p.m.	—1	.030	.025	2	28 ω
126-A							4 Lead...								
123	B-4	3505	24	C.C.	4	Oldham......	5 Post...	6	55 200	3 to 4 @ 1250 r.p.m.	—1	.030	.025	2	28 ω
123	B-4	3505	24	C.C.	4	Oldham......	5 Post...	6	55 200	3 to 4 @ 1250 r.p.m.	—1	.030	.025	2	28 ω
125	D-3	3508	24	C.	4	Oldham......	4 Post...	6	55 200	3 to 4 @ 1250 r.p.m.	—1	.030	.025	2	28 ω
124	D-8	3510	24	C.	4	Flange.......	4 Post...	6	55 200	3 to 4 @ 1250 r.p.m.	—1	.030	.025	2	28 ω
	D-4	3551	16	C.C.	4	Oldham......	4 Lead...	7	44 240	3 to 4 @ 1250 r.p.m.	—1	.030	.025	2	28 ω
	D-5	3552	24	C.	4	Oldham......	4 Lead...	6	55 200	3 to 4 @ 1250 r.p.m.	—1	.030	.025	2	28 ω
126-A	F-5	3550	16	C.	4	Sprocket.....	4 Lead...	7	44 240	3 to 4 @ 1250 r.p.m.	—1	.030	.025	2	28 ω
80-A	D-10	3546	24	C.	4	Sprocket.....	4 Lead...	6	55 200	3 to 4 @ 1250 r.p.m.	—1	.030	.025	2	28 ω
841	G-1	3554	12	C.	3.990	Sprocket.....	2 Post...	$7\frac{1}{2}$	36 240	1 to $1\frac{1}{2}$ @ 1000 r.p.m.	—1	.030	No Li	miting	Relay
841	G-1	3555	12	C.C.	3.990	Sprocket.....	2 Post...	$7\frac{1}{2}$	36 240	1 to $1\frac{1}{2}$ @ 1000 r.p.m.	—1	.030	No Li	miting	Relay
841	G-2	3556	24	C.	3.990	Sprocket.....	2 Post...	6	55 220	1 to $1\frac{1}{2}$ @ 1150 r.p.m.	—1	.030	No Li	miting	Relay
841	G-2	3557	24	C.C.	3.990	Sprocket.....	2 Post...	6	22 220	1 to $1\frac{1}{2}$ @ 1150 r.p.m.	—1	.030	No Li	miting	Relay

Replacing Dodge Chain. When the driving chain on any equipment operated in this manner has worn to a point where it no longer makes proper contact with the sprockets (the chain being adjusted to the correct tension), it will be necessary to replace it. While the following instructions for "fishing" the chain through the housing apply particularly to the Dodge car, with little modifications here and there they will be found equally applicable to all similar installations.

Having removed the old chain, pass a short piece of wire through the end of the new chain, Fig. 308. Then start the chain on the lower side of the sprocket, as shown in the illustration, hooking the wire through the sprocket to keep the chain in mesh, and slowly turn the engine over by hand until the chain appears at the top of the sprocket. Then remove the wire from the sprocket, hold the end of the chain, and continue to turn the engine over until the chain is in a position to apply the master link.

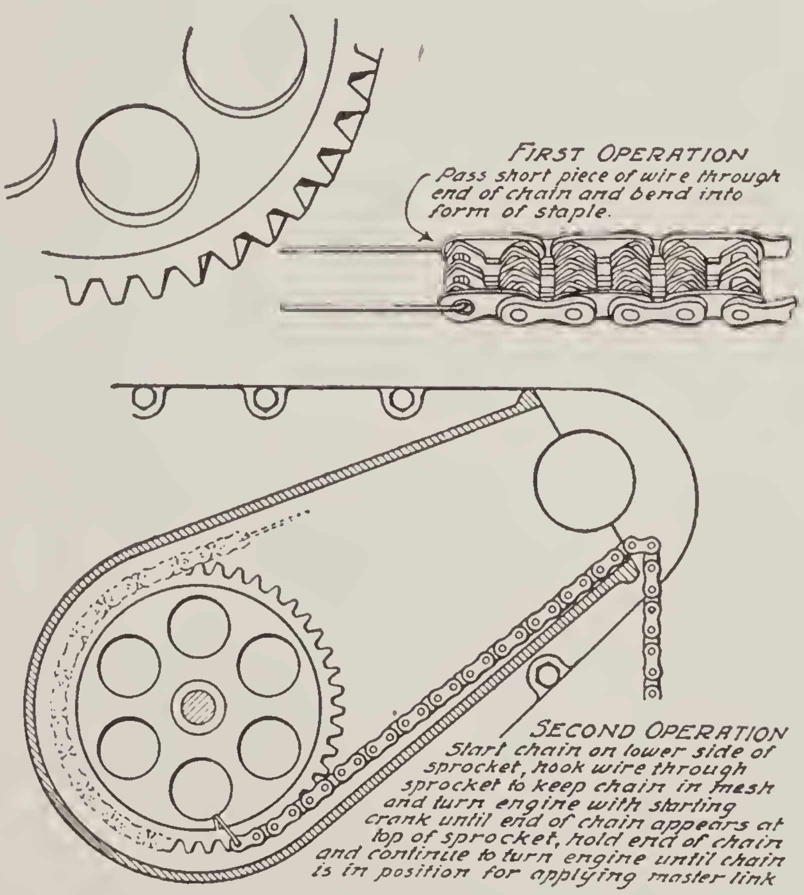


Fig. 308.—Diagram Showing Method of Inserting Chain in North East Equipment on Dodge Cars

Mechanical and Electrical Characteristics. When it is desired to make bench tests of any of the North East apparatus with the aid of the outfit described in connection with the Gray & Davis tests, the data shown in Table V will be found valuable for checking purposes. The left-hand columns give the mechanical characteristics, with the aid of which the unit may be identified, while the right-hand columns give the electrical characteristics, such as the charging rate, torque in foot-pounds with given current input, cutting-in and cutting-out points of the master relay (battery cut-out), air gaps for the limitation relay, and the resistance of the units.

REMY SYSTEM

Six-Volt; Two-Unit; Single-Wire

Generator. Of the multipolar (four-pole) shunt-wound type of generator combined with ignition timer and distributor and designed to be driven at $1\frac{1}{2}$ times crankshaft speed, several models are made, of which one is shown in Fig. 309. In this case, both the regulator for the generator and the battery cut-out are mounted directly on the generator. On some of the models only the regulator is so mounted, the cut-out being placed on the dash of the car, while on others no independent regulating device is required as the third-brush type of regulation is employed (on bipolar generator).

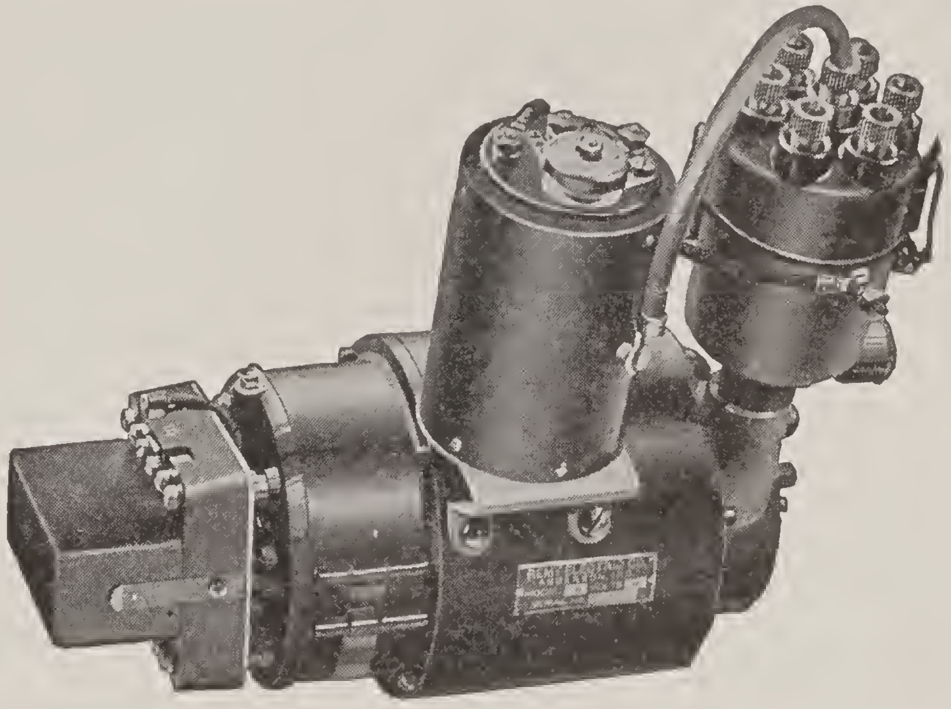


Fig. 309. Remy Ignition Generator and Distributor
Courtesy of Remy Electric Company, Anderson, Indiana

Regulation. In accordance with the model of generator and the requirements of the engine to which it is to be fitted, either the constant-voltage method of regulation using a vibrating regulator mounted on the generator or the third-brush method is employed.

Constant-Voltage Method. The regulator for the generator is similar in principle to that described in connection with the Bijur system. It consists of an electromagnet; two sets of contact points, two of which are mounted on springs; a pivoted armature which may move to make or break the circuit; and a resistance unit. When running at too slow a speed to produce its maximum output, the generator field is supplied with current passing directly through the regulator contact points, which are held together by a spring. As soon, however, as the speed of the generator increases to a point where it tends to cause its output to exceed the predetermined maximum, the charging current which is flowing through the coil of the electromagnet energizes it so such an extent as to cause it to

pull the armature down. This separates the contacts and causes the field current to pass through the resistance unit, thus decreasing the field current and, in turning, decreasing the generator output, which reduces the exciting effect on the electromagnet and causes it to release its armature, cutting the resistance out of the field circuit. The latter immediately builds up again, and the operation is repeated as long as the speed remains excessive for the generator, which is thus supplied with a pulsating current to excite its fields, and its output is held at a practically constant value.

Third-Brush Method. The third-brush method of regulation is based upon the distortion of the magnetic field of a generator at high speeds. When running at low speeds, the magnetic flux of a generator is evenly distributed along the faces of its field pole pieces, but at high speeds there is a tendency to drag it out of line in the direction of the rotation of the armature. It is then said to be distorted. The third brush, which supplies the exciting current to the field winding, is so located with relation to the main-line brush of opposite polarity that this distortion of the magnetic flux reduces the current which it supplies to the fields. This decrease in the exciting current of the field causes a corresponding decrease in the output of the generator, and as the distortion of the magnetic flux is proportional to the increase in speed, the generator output falls off rapidly the faster it is driven above a certain point, so that it is not damaged when the automobile engine is raced.

Thermostatic Switch. More of the current produced by the generator is used for lighting purposes in winter than in summer, in the proportion that the demands for house lighting vary with the change of the seasons. Added to the decreased efficiency of the storage battery in cold weather, this tends to place a greatly increased load on the generator in the winter months. If the generator, as installed, were regulated to produce sufficient current to take care of this maximum demand, it would keep the storage battery in a constant state of overcharge in summer and would be likely to ruin the plates through excessive gassing. The Remy engineers have accordingly developed a method of regulation that will automatically compensate for the difference in the demand with the changing seasons, consisting of a thermostatic switch in connection with the third-brush control; it will be found, among others, on the Reo 1917 models.

To gain a clear idea of the action of an electric thermostat, the heating effect of the current must be kept in mind; also that different metals have different coefficients of expansion, i.e., some will expand more than others under the influence of the same degree of heat. Electric thermostats have been in use for years as automatic fire alarms and as temperature-controlling devices in incubators and for residence heating, and within the past few years they have come into use on the automobile to control the circulation of the cooling water and the suction of the engine in accordance with variations in the temperature. The device consists of a thermal member, or blade, of two different metals riveted together at their ends. This member is held fast at one end and at the other it carries a contact point, designed to complete the circuit by touching a stationary contact. Under the influence of an increase in temperature, one of the metals

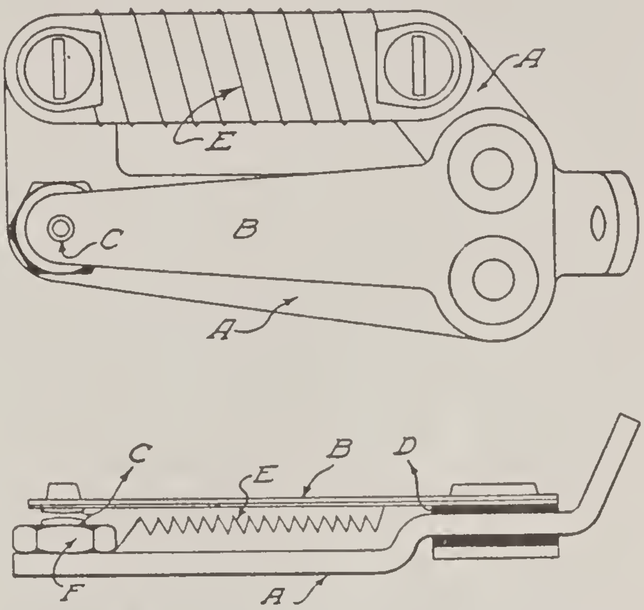


Fig. 310. Details of Remy Thermostatic Switch

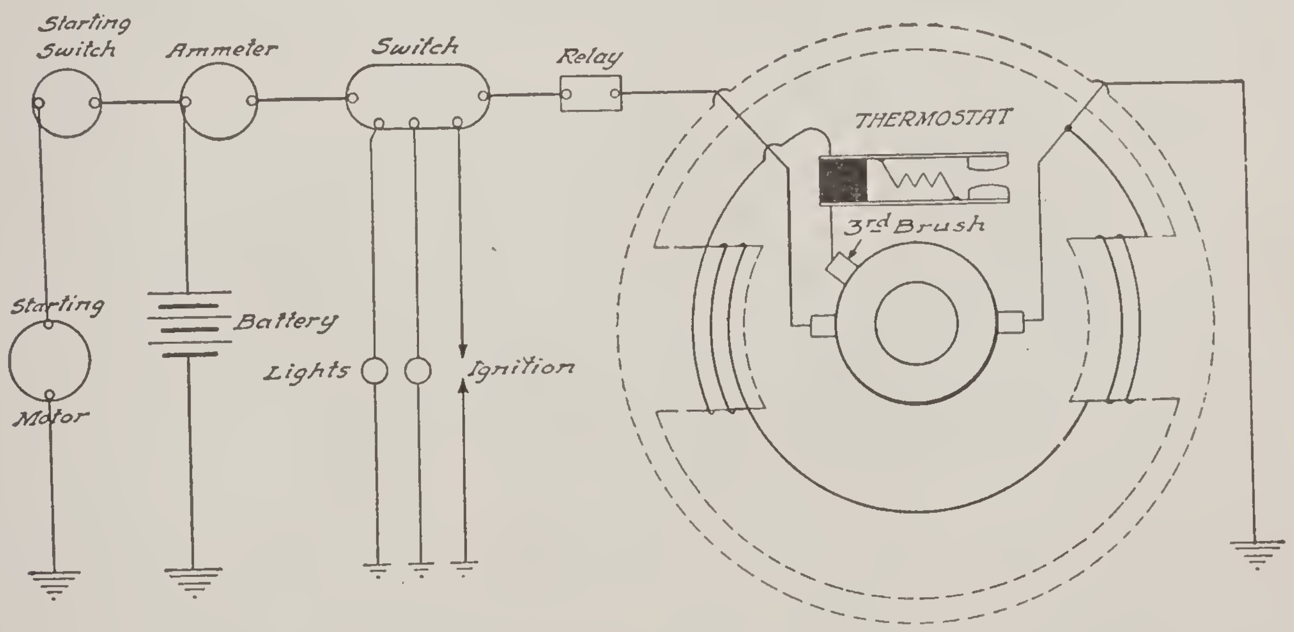


Fig. 311. Wiring Diagram of Switch Connections

expands more than the other and thus springs this member, or blade, away from the stationary contact.

The details of the Remy thermostat are shown in Fig. 310. *B* is the thermo-member carrying the silver contact *C*, and is supported on

a strip of steel A. A also carries the resistance unit E, which is a short coil of high-resistance wire wound on heavy mica insulation. A and B are riveted together at the end D so as to insulate them from each other. The two metals composing B are spring brass and nickel steel, the strip of spring brass being placed on the lower side of the blade. Sufficient tension is placed on this strip, by means of the adjusting nut F, to keep the points firmly in contact at temperatures below 150° F. This adjustment is made by the manufacturer and is permanent.

As shown in the wiring diagram, Fig. 311, which illustrates the relation of the thermo-switch to the third-brush method of regulation, it will be noticed that the switch is placed near the commutator of the generator, as that is the hottest part of the machine when it is in

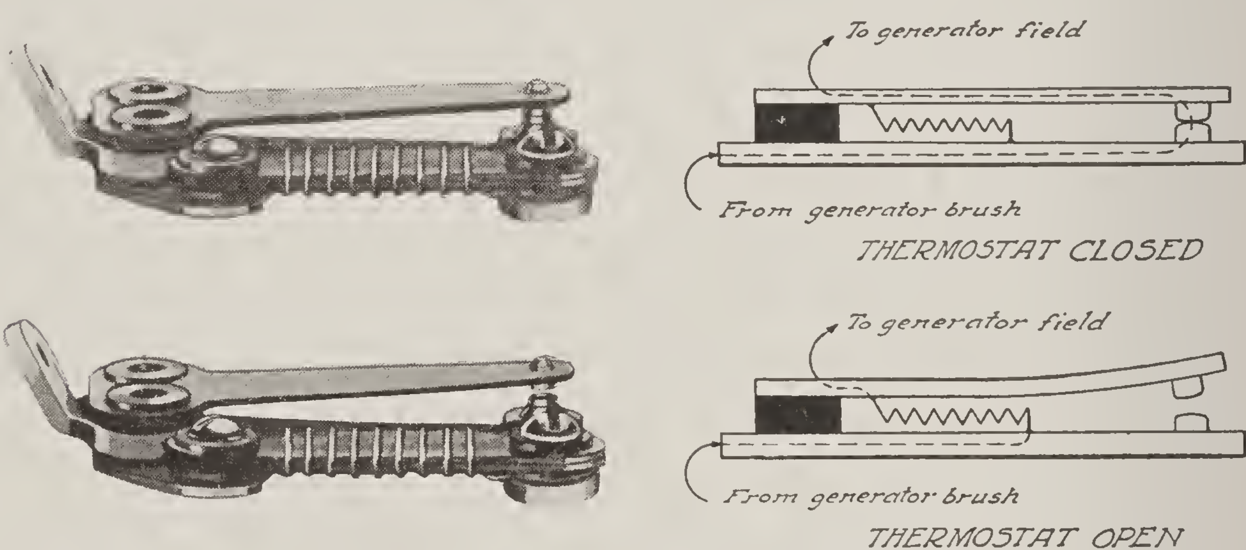


Fig. 312. Photographic Reproductions and Diagrams of Action of Thermostatic Switch When Closed and Opened
Courtesy of Remy Electric Company, Anderson, Indiana

operation. It will be noticed also that when the contact points of the thermo-switch are open, as shown in the illustration, the current supplied to the field by the third brush must pass through the resistance unit of the switch, thus cutting it down. This is the position for warm-weather running, when not so much of the current is required for lighting, and when the storage battery is at its best. When the temperature of the air about the thermo-switch exceeds 150° F., the movable blade is warped upward, owing to the greater coefficient of expansion of the brass as compared with that of the nickel steel. The contact points will accordingly remain open as long as the temperature exceeds this degree. When it falls below that point, the quicker contraction of the brass pulls the blade down, and the points again make contact, cutting out the resistance and increasing the output

of the generator, diagrams of the thermo-switch in its closed and open positions being shown at the right, and a halftone of the switch at the left in Fig. 312, while the curves, Fig. 313, show the increase in the current output brought about by the closing of the thermo-switch points. The path taken by the current when the points are open and when they are closed is indicated by the dotted lines in the diagrams, Fig. 312. The curves show that with the thermo-switch open, the maximum current output of the generator is limited to 14 to 15 amperes, while with the switch closed it rises to 20 to 22 amperes. The switch will normally remain closed after the engine has been idle for any length of time; but in summer it will open after driving a few miles, while in winter it will probably remain closed, no matter how much the car is driven.

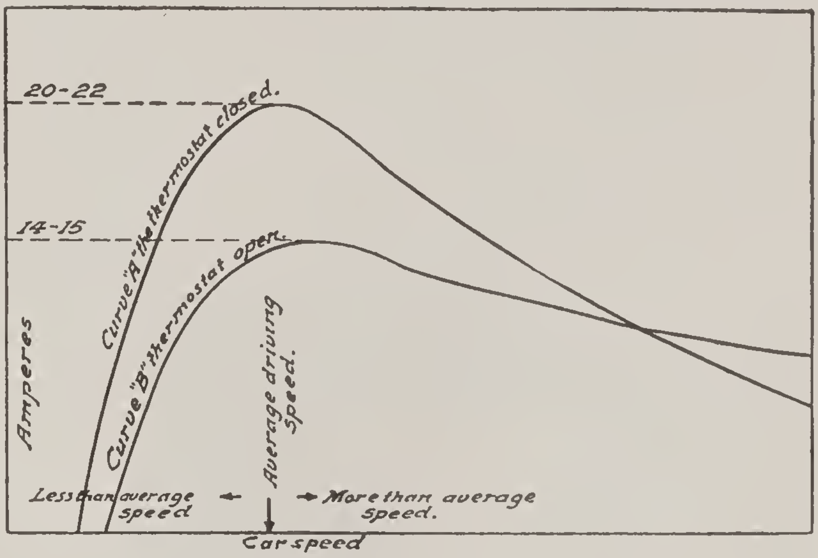


Fig. 313. Output Curves of Remy Patented Generator

Starting Motor. The motor is the 6-volt 4-pole series-wound type, illustrated in Fig. 314, mounted either with gear reduction

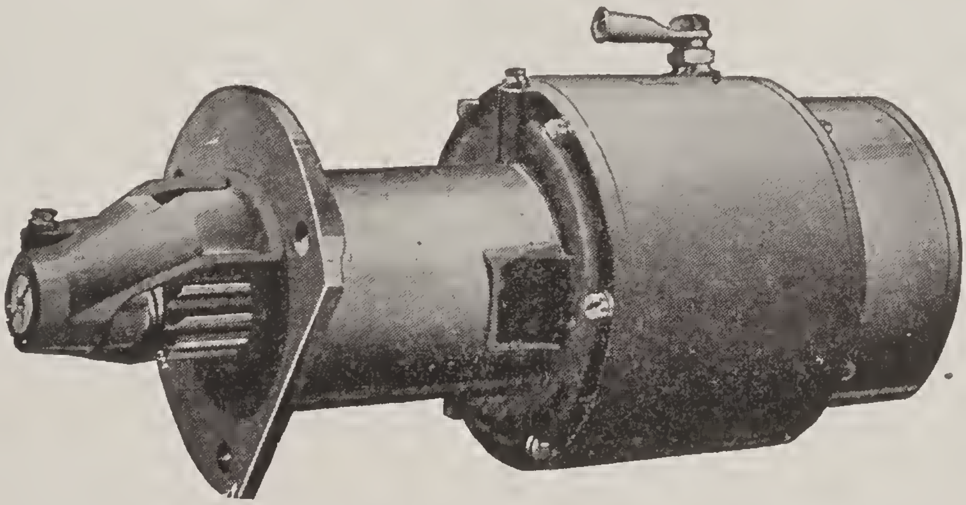


Fig. 314. Remy Starting Motor with Outboard Type Bendix Pinion

and over-running clutch, or with automatically engaging pinion for direct engagement with flywheel gear, as described in connection with the Auto-Lite. The latter is known as the Bendix gear. The control is by independent switch.

Instruments and Protective Devices. An indicator, or *telltale*, shows when the battery is charging or discharging, and also serves

to indicate any discharge, in all except the starting-motor circuit, due to grounds or short-circuits. All lamp circuits are fused, and a fuse is inserted in the regulator circuit.

Remy Single-Unit

A Mechanical Combination. While termed a single-unit type, this is actually two independent units combined, *mechanically* and *not electrically*, so that it bears no resemblance to the single unit on which both field and armature windings are carried on the same pole pieces and armature core. The field frame for the two units is a single casting, Fig. 315, but the magnetic circuits of both the generator and the motor are entirely independent, and each is a separate unit. They are combined in this manner solely for convenience in mounting where space is limited. The vibrating type of voltage regulator is employed in connection with the generator, while the starting motor operates through a train of reducing gears and an over-running clutch. Apart from the combination of the two units and the method of starting drive which this entails, the system is the same in its essentials as where the units are mounted independently.

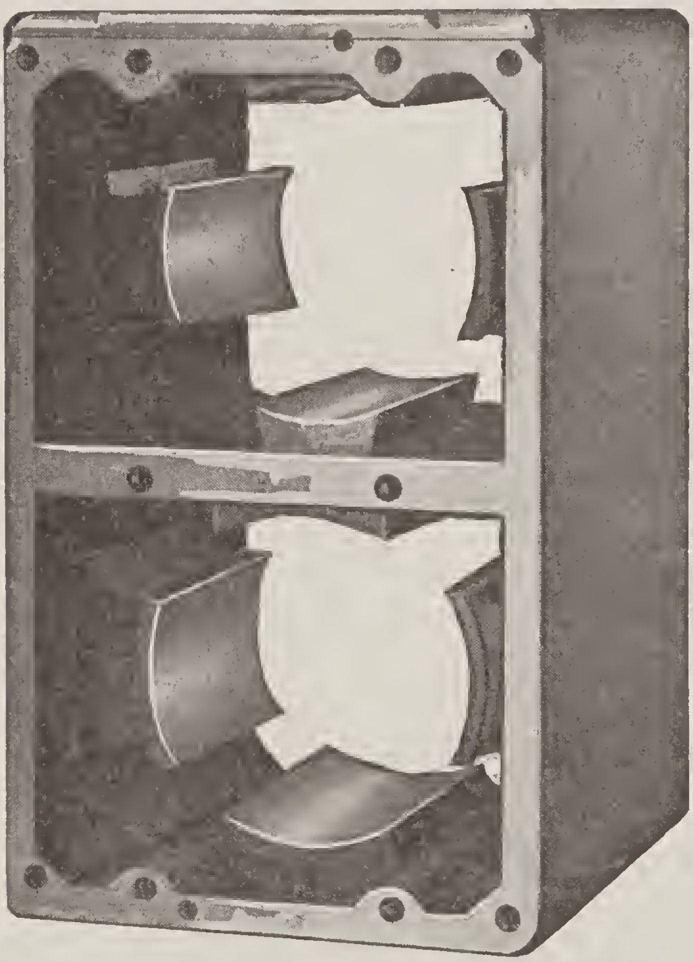


Fig. 315. Combined Field Frame of Generator and Motor for Remy Single-Unit System

Wiring Diagrams. Velie. Fig. 316 shows the installation on Velie, Model 22, and the details will be plain with further explanation. The "ratchet reversing switch", shown in the diagram, is for controlling the ignition current, and it is designed to reverse the direction of this current each time the switch is turned on in order to prevent the formation of a crater and cone on the ignition interrupter contacts, as previously described, thus keeping the points in good work-

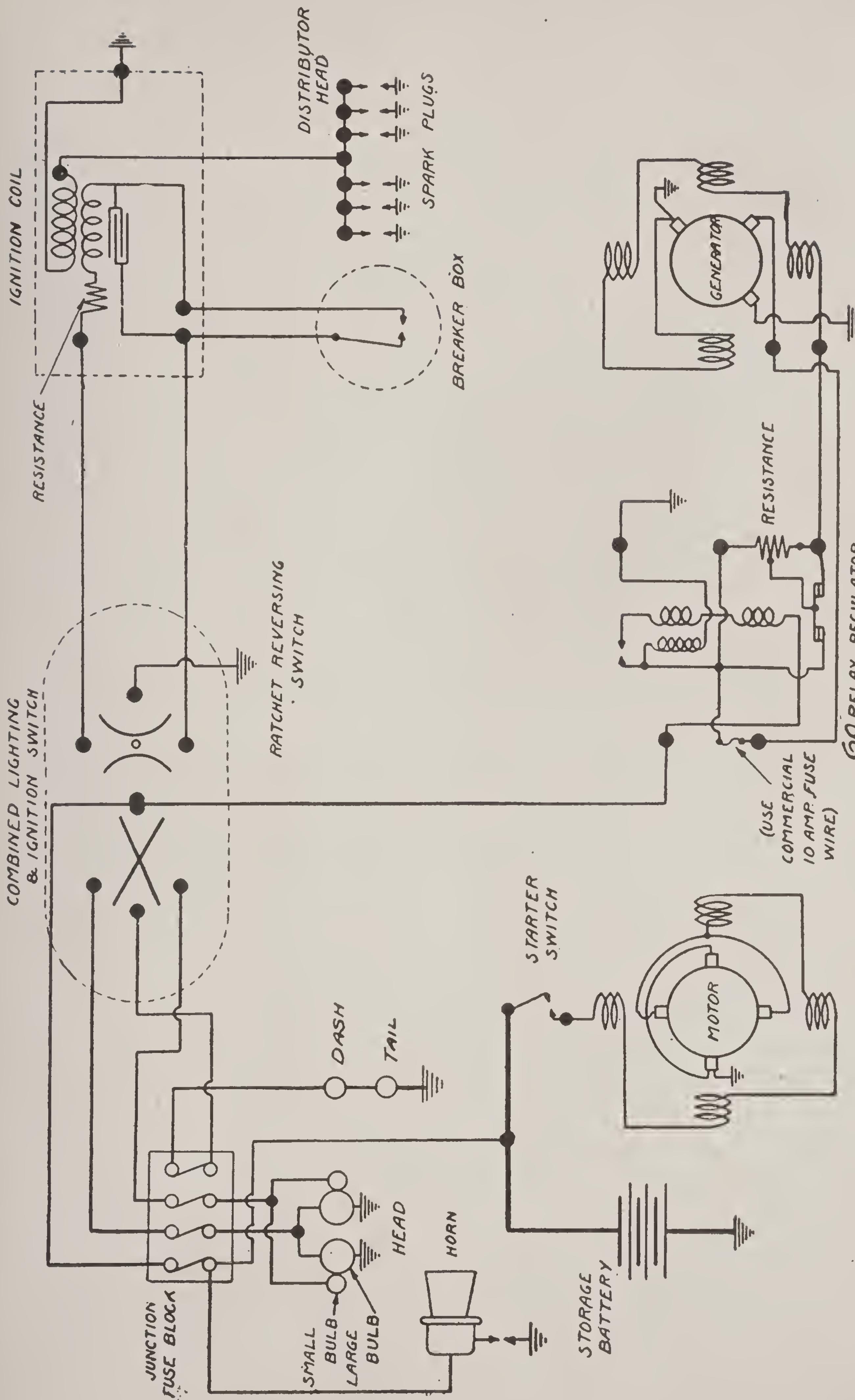


Fig. 316. Wiring Diagram for Remy Installation on the Velie, Model 22

ing order for a much longer period. The dash and tail lights are $3\frac{1}{2}$-volt lamps, wired in series, so that the failure of one puts the other out, thus giving an indication at the dash of the failure of the tail light.

Oakland. The Remy installation on Oakland Model 32 is shown in Fig. 317. The chief distinction between this and the previous diagram is the employment of a single 10-ampere fuse on the lighting circuits instead of independent fuses on each circuit. "Breaker box" refers to the ignition-circuit contact-breaker, or interrupter, as it is variously termed. The starting motor in this case is fitted with the Bendix drive.

Reo. On the Reo installation, Fig. 318, the starting motor is mounted on the transmission housing and drives to a shaft of the latter through a worm gear. In this case the starting switch is mounted directly on the starting motor, and an ammeter is supplied on the charging circuit instead of a telltale, or indicator.

National. A typical installation of the single unit, or so-called double-deck unit, is shown in Fig. 319. This is on the National six-cylinder model and is a two-wire system. It is not interconnected with the ignition system, so there are no ground connections, and no fuses are employed.

Instructions. These instructions cover the systems which include the ignition. For instructions applying to the double-wire system on cars having an entirely independent ignition system, like the National, see instructions under Auto-Lite, Delco, Gray & Davis, and others, for failure of generator or motor, short-circuits, and the like.

Battery Discharge. In systems of this type, discharge of the battery may be due to failure to open the ignition switch after stopping the car. The amount of current consumed is small but in time it will run the battery down. The indicator or the ammeter, according to which is fitted, will show a discharge. An entire failure of the current may indicate: a loose connection at battery terminals, at battery side of starting switch in connection with a blown main fuse (Oakland), or a loose battery ground connection; a loose connection at motor side of starting switch or at starting motor, or a broken wire between the switches. (See previous instructions on other makes for testing with lamp set for broken or grounded circuits.)

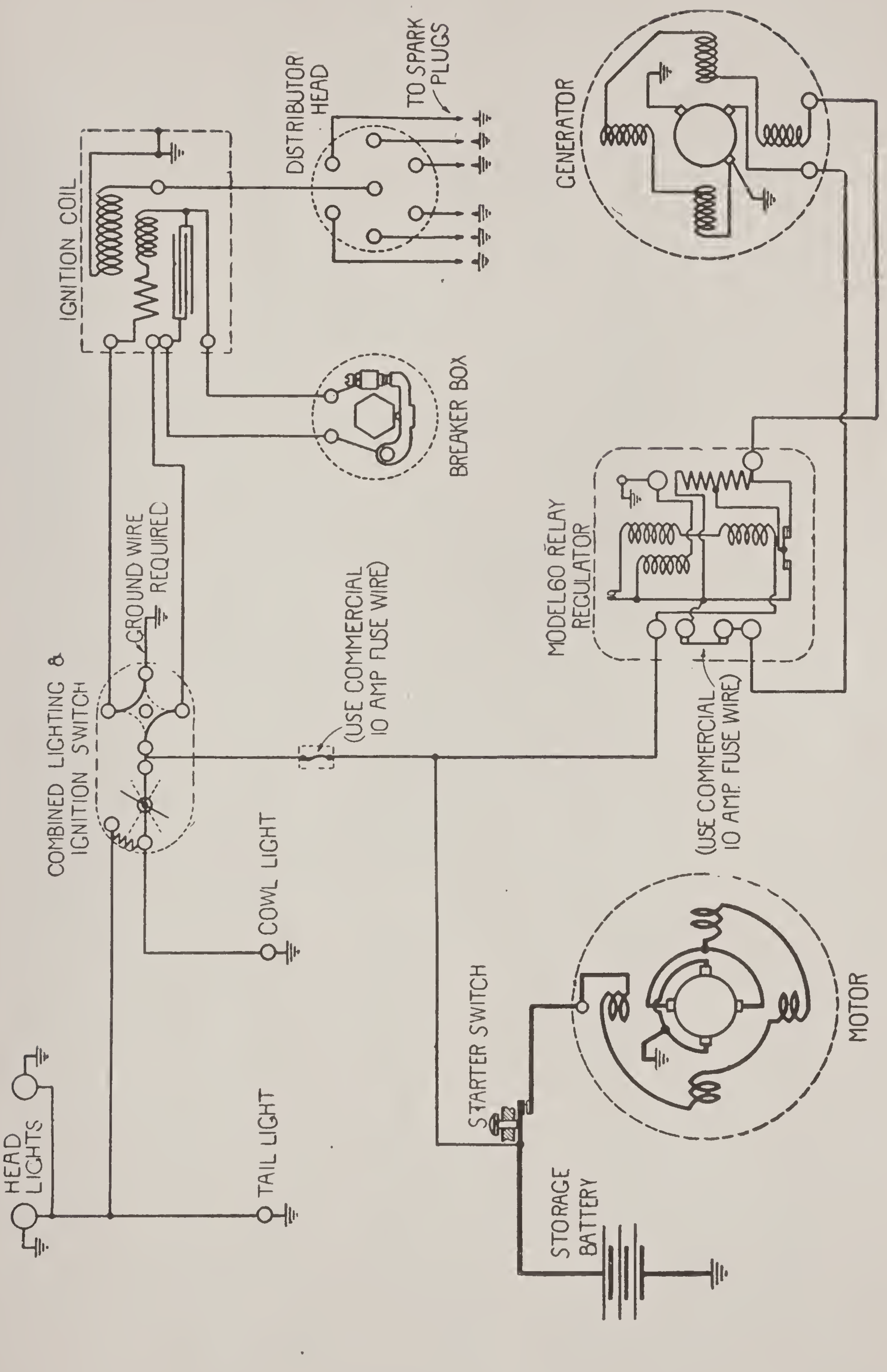


Fig. 317. Wiring Diagram for Remy Installation on the Oakland, Model 32

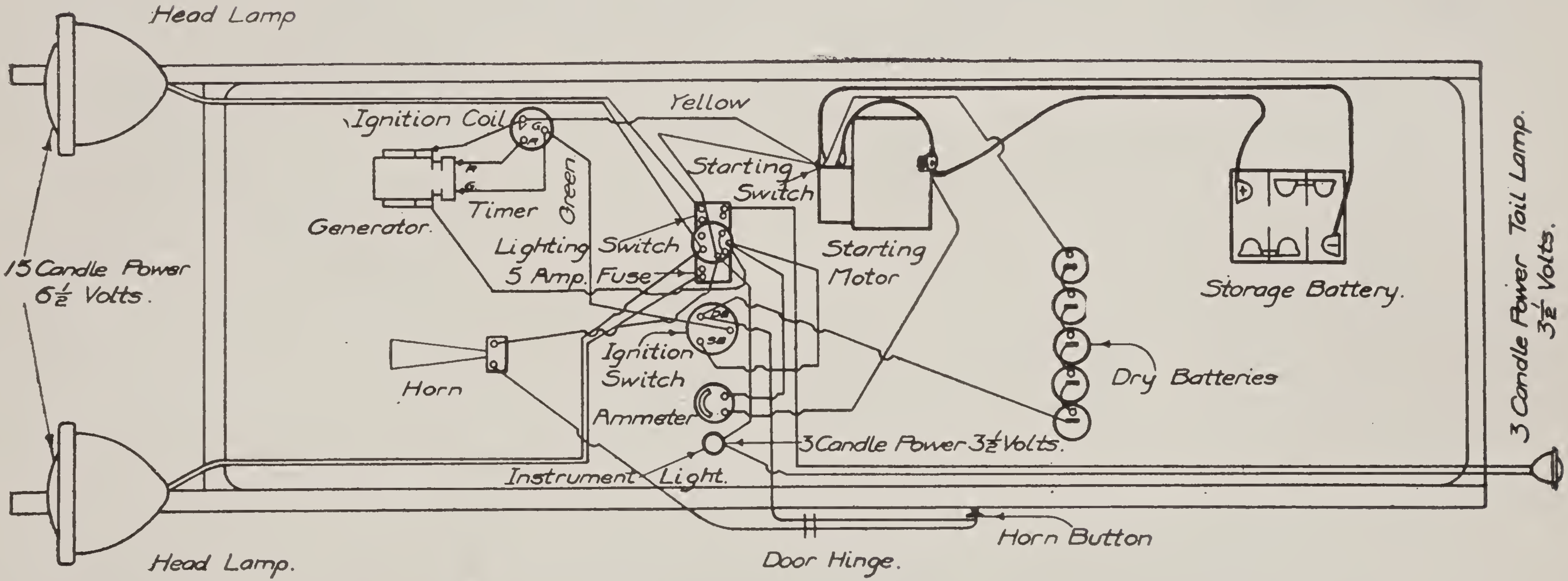


Fig. 318. Wiring Diagram for Remy Installation on "Reo the Fifth"

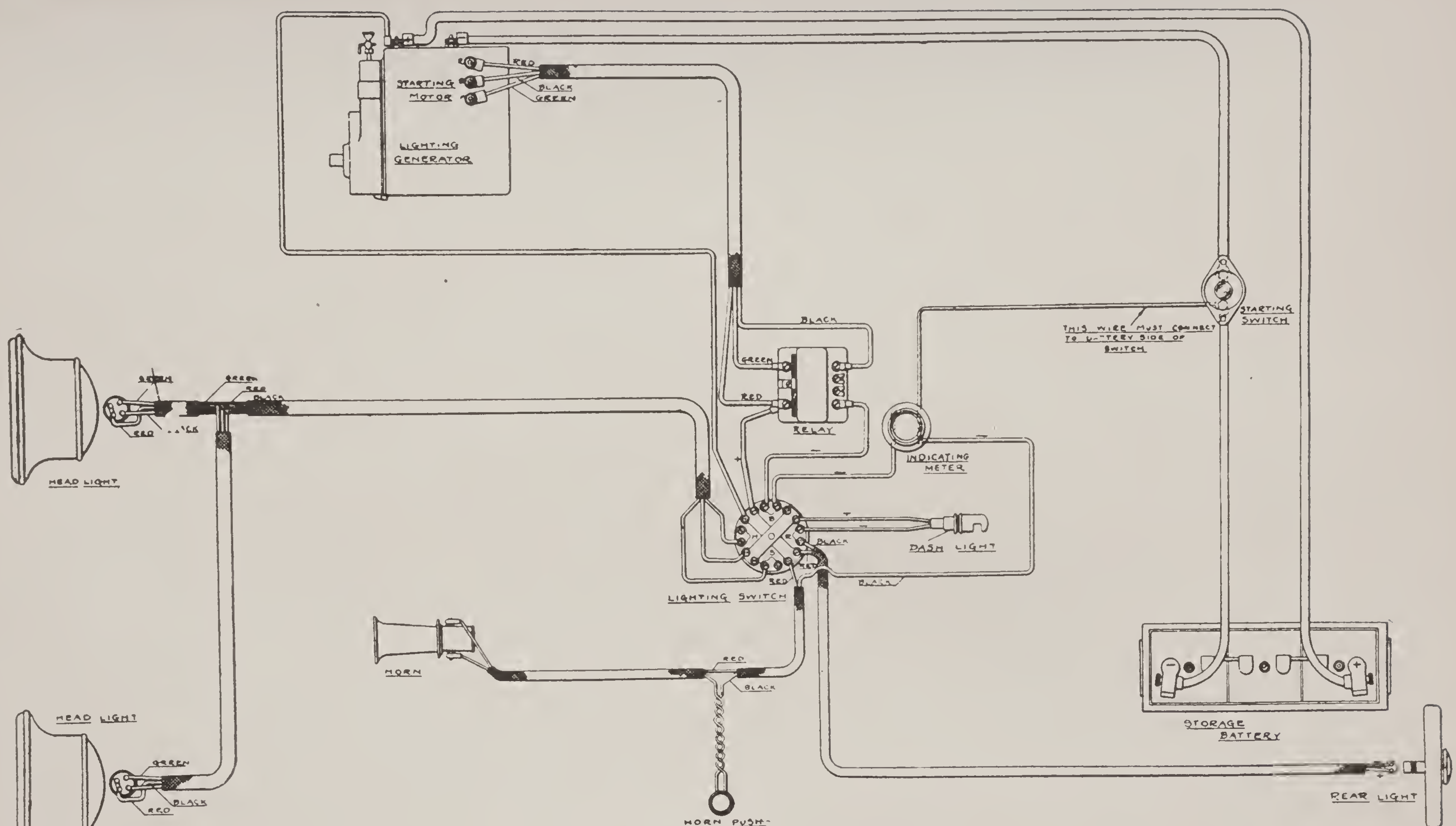


Fig. 319. Wiring Diagram for Remy Double-Deck Unit on the National Six

Failure of Lighting, Ignition, Starting. When the lights and ignition fail but the starting motor operates, it indicates a short or open circuit between the starting switch and the main fuse (Oakland). This fuse should first be examined and, if blown, a search should be made for the ground or short-circuit causing it, before putting in a new fuse. The fault will be in the wiring between the switch, lights, and ignition distributor. See that all connections, including those on fuse block, are tight. When the lights fail but the ignition and starting motor operate, the trouble will be found either in the circuits between the lighting switch and lamps; in the lamps themselves, as a burned-out bulb causes a short-circuit; or from loose connections in these circuits. Failure of the ignition, with the remainder of the system operating, may be traced to loose connections at the ignition switch, coil, or distributor; poor grounding of the ignition switch on the speedometer support screw; or to open or short-circuits between the ignition switch and the distributor. Further detail instructions on ignition are given in Ignition, Part II.

Dim Lights. When all the lights burn dimly, the most probable cause is the battery, but if a test shows this to be properly charged, a ground between the battery and the starting switch or between the latter and the generator may be responsible for leakage. Other causes are the use of higher candle-power lamps than those specified, the use of low efficiency carbon-filament bulbs, or failure of the generator to charge properly.

Examine generator-field fuse and if blown, look for short-circuits before replacing, as previously instructed. A simple test of the generator may be made by switching on all the lights with the engine standing. Start the engine and run at a speed equivalent to 15 miles per hour or over. If the lights then brighten perceptibly, the generator is operating properly. This test must be made in the garage or preferably at night, as the difference would not be sufficiently noticeable in daylight.

If the generator fuse is intact, examine the regulator relay contacts. If the points are stuck together, open by releasing the relay blade with the finger. Clean and true up points as previously instructed and clean out all dust or dirt from relay before replacing cover. Particles of dirt lodged between the points will prevent the generator from charging properly.

The failure, flickering, or dim burning of any single lamp will be due to a burned-out bulb, to loose or frayed connections at lamp or switch, to a bulb loose in its socket, or to an intermittent ground or short-circuit in the wiring of that particular lamp, or to the frame of the lamp nor being grounded properly. Where dash and tail lamps are in series, examine both bulbs and replace the one that has burned out. Test with two dry cells connected in series.

Ammeter. When the indicator, or ammeter, does not register a charge with the engine running with all the lights out, stop the engine and switch on the lights. If the instrument gives no discharge reading, it is faulty. If it shows a discharge, the trouble is in the generator or connections. In case the ammeter registers a discharge with all the lights off, ignition switch open, and engine idle, examine relay contacts to see if they remain closed. If not, disconnect the battery. This should cause the ammeter hand to return to zero; if it does not, the instrument is out of adjustment. With the ammeter, or indicator, working properly, and the relay contacts in good condition, a discharge then indicates a ground or short-circuit. When examining the relay for trouble, do not change the adjustment of the relay blade.

SIMMS-HUFF SYSTEM

Twelve-Volt; Single-Unit; Single-Wire

Dynamotor. The dynamotor is of the multipolar type having six poles, as illustrated in Fig. 320, which shows the field frame, coils, and poles. Fig. 322 illustrates the assembled brush rigging, while Fig. 321 shows the complete unit with the commutator housing plates removed.

Regulation. Regulation is by reversed series field, in connection with a combination cut-out and regulator. The regulator is of the constant-potential type and is combined with the battery cut-out. It is connected in circuit with the shunt field of the generator, and the vibrating contacts of the regulator cut extra resistance into this circuit when the speed exceeds the normal generating rate. There is also a differential compound winding of the fields, the two halves of which oppose each other at high speeds.

Instruments. An ammeter is supplied, showing *charge* and *discharge*.

Dynamotor Connections. The dynamotor has two connections, one at the bottom of the forward end plate, marked DYN+, and the other on top of the field yoke designated as FILED. As the system is a single-wire type, the opposite sides of both circuits are grounded within the machine itself. The terminals on the cut-out are marked BAT+, DYN+, and DYN−, BAT−, and FLD.

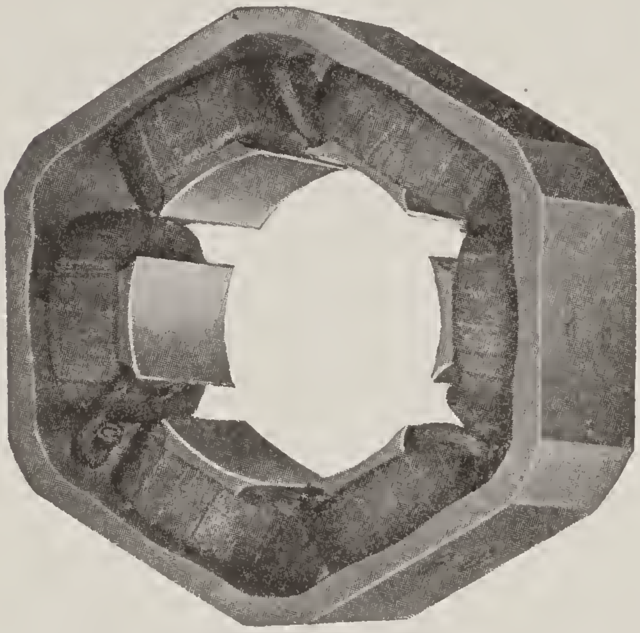


Fig. 320. Field Frame, Poles, and Windings for Simms-Huff Dynamotor

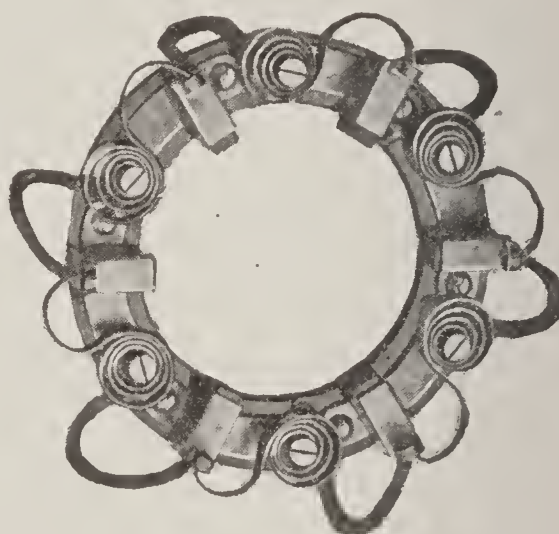


Fig. 321. Brush Rigging for Simms-Huff Dynamotor

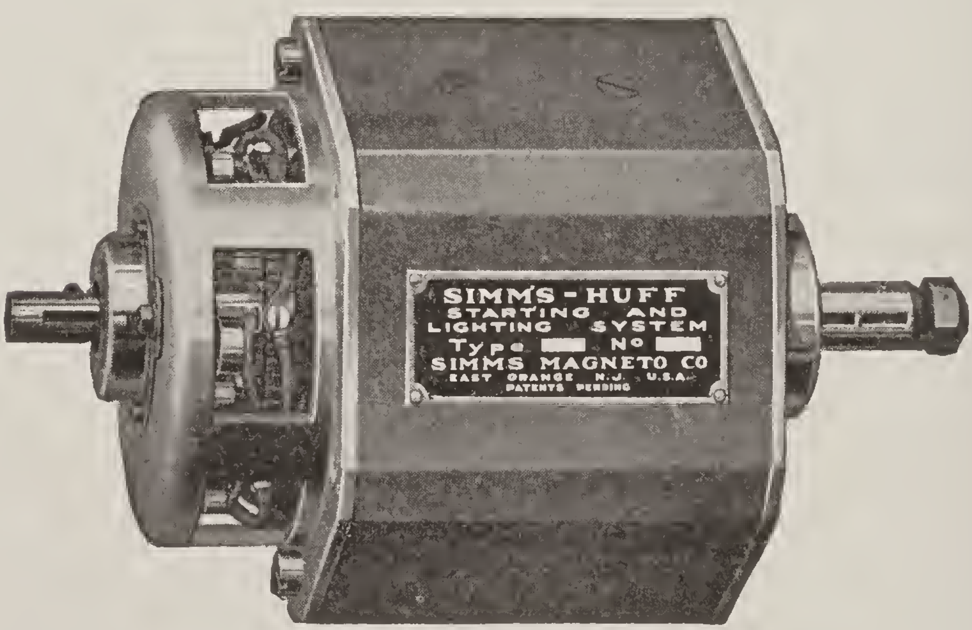


Fig. 322. Simms-Huff Dynamotor with Commutator Housing Plates Removed
Courtesy of Simms Magneto Company, East Orange, New Jersey

BAT+ connects through a 12-gage wire to the negative side of the ammeter and thence to a terminal on the starting switch. This connects it permanently to +R of the battery through the ammeter. This wire supplies the current to the distributing panel, from which

current is supplied to the lamps and horn. DYN+ connects through a similar wire to the plus terminal of the dynamo, while DYN− and

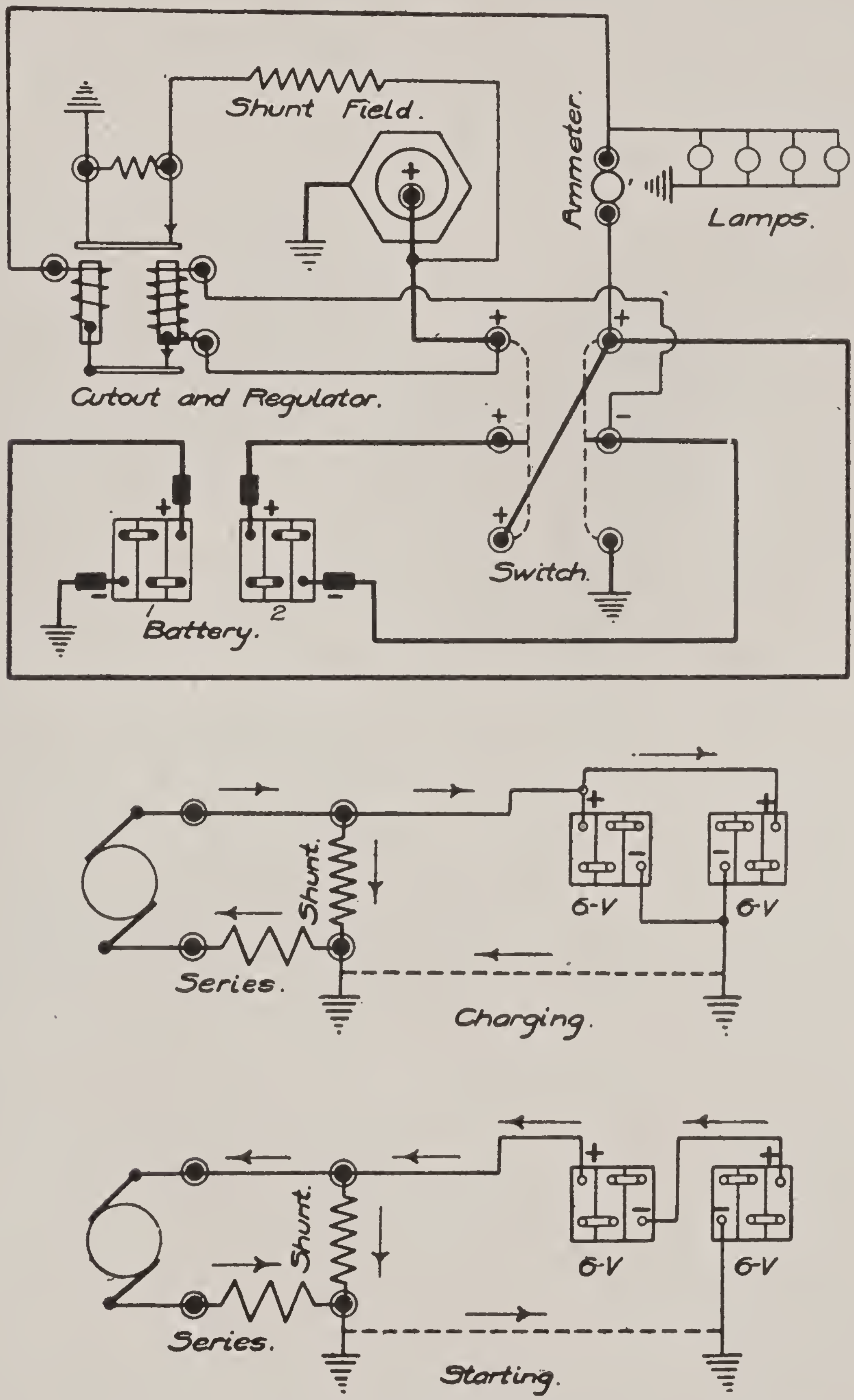


Fig. 323. Wiring Diagram for Simms-Huff Starting and Lighting Systems

BAT− connect with the −L terminal of the storage battery through a wire of the same size.

Change of Voltage. The system is known as 6—12-volt type, signifying that the current is generated at 6 volts, but is employed for

starting at 12 volts. There are accordingly 6 cells in the storage battery, and the latter is charged by placing the two halves of it, consisting of two 3-cell units, in parallel. This is indicated in the

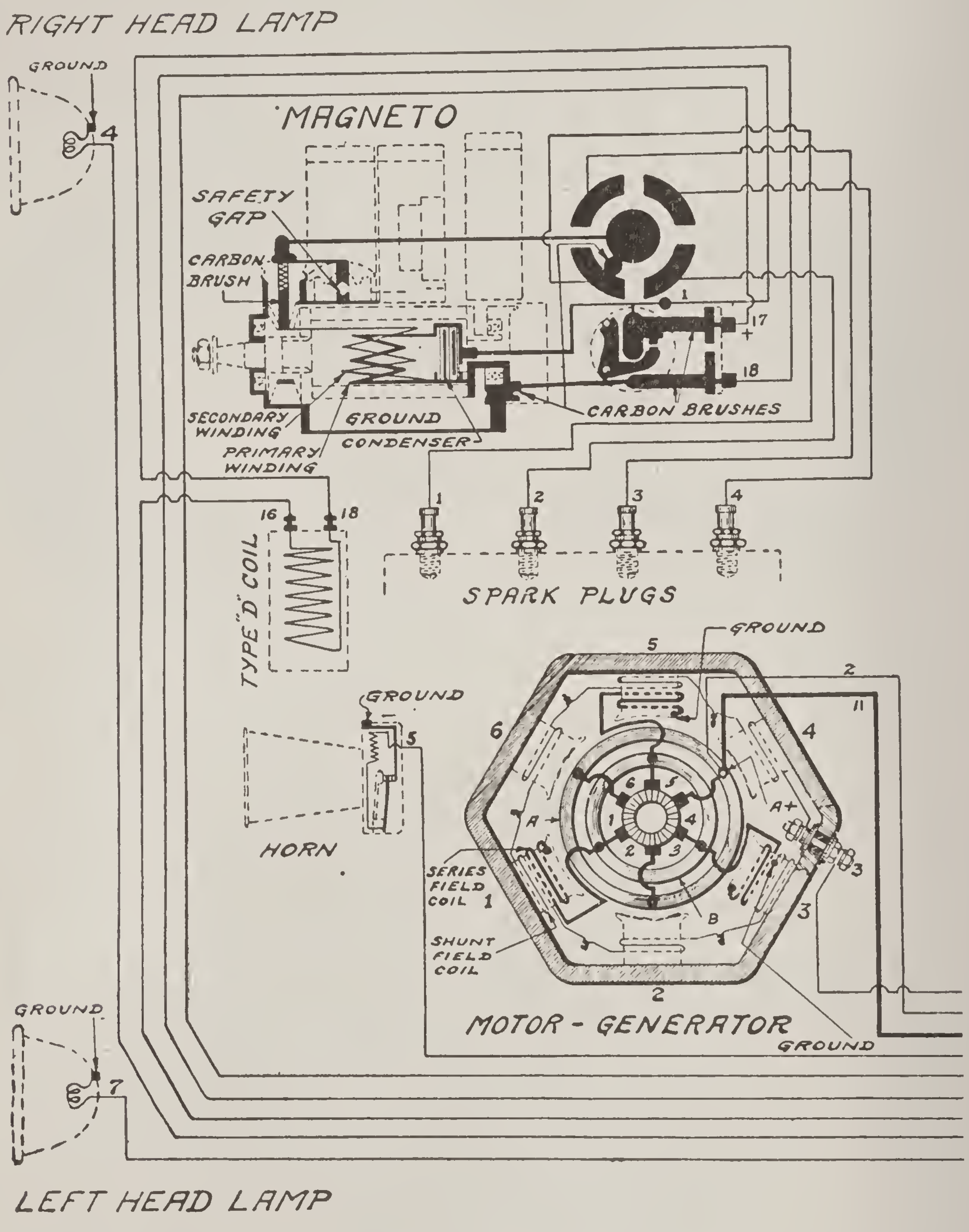


Fig. 324a. Complete Wiring Diagram for 1916-17 Maxwell Cars (see Fig. 324b)
Courtesy of Simms Magneto Company, East Orange, New Jersey

upper diagram, Fig. 323, also in the middle diagram, which shows the connections for charging. In the lower diagram of the figure are shown the starting connections, the switch being connected to throw the 6 cells of the battery in series, so that the unit receives current at

12 volts for starting, thus doubling its power. Six-volt lamps are employed and are supplied with current from the left-hand section of the battery, marked *1*, as shown in the upper part of the diagram.

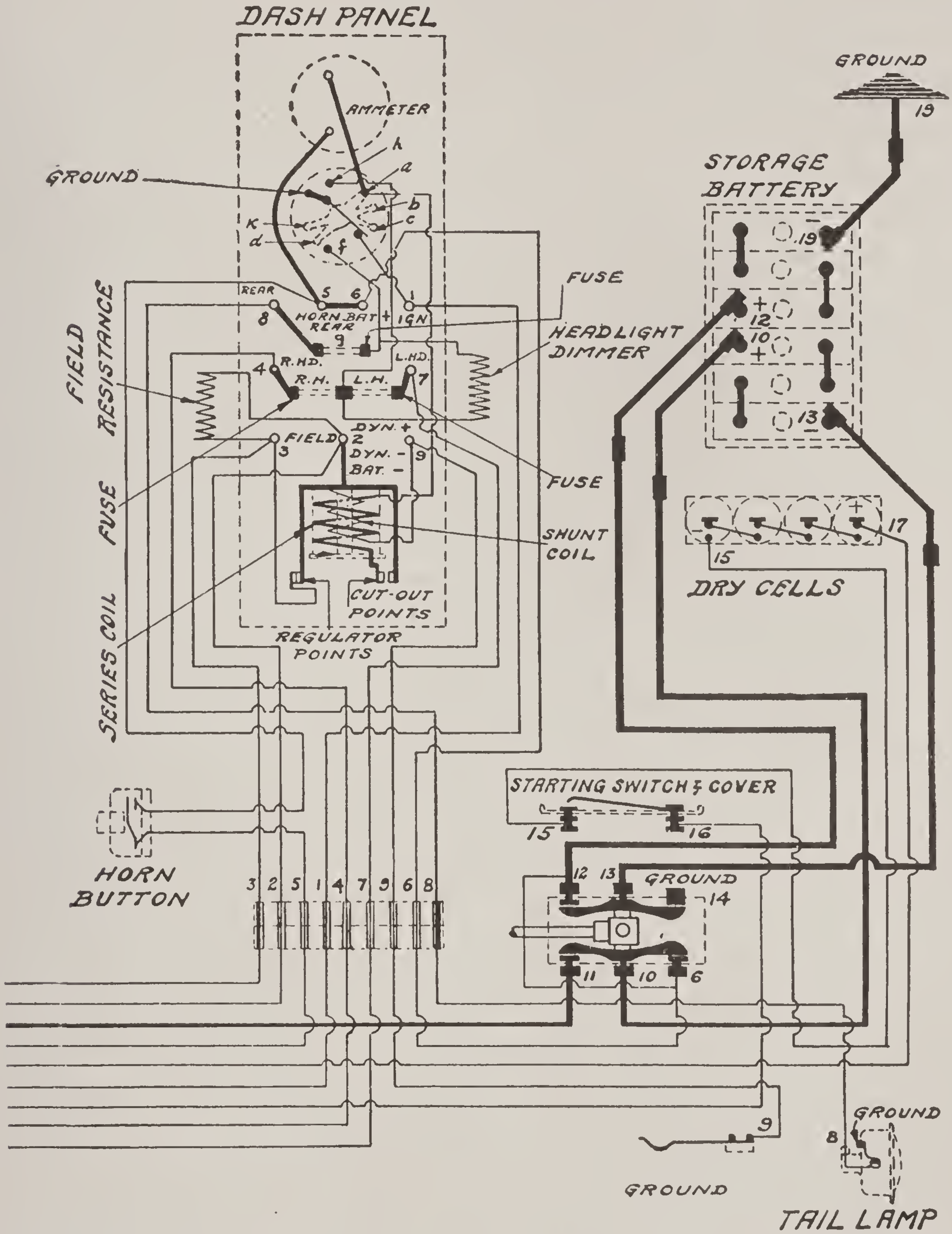


Fig. 324b. Complete Wiring Diagram for 1916-17 Maxwell Cars, Showing Details of Dash Panel and Batteries

Courtesy of Simms Magneto Company, East Orange, New Jersey

Starting Switch. This is mounted on the left side of the gear-box housing (Maxwell) and is so arranged as to connect the entire battery in series for starting, thus giving current at 12 volts for this purpose. The same movement of the starting switch also puts the

battery in circuit with the ignition system so that, as soon as the engine starts and the switch is released, it automatically disconnects the battery from the ignition, and the engine then runs on the magneto (dual ignition system).

Wiring Diagram. Fig. 324*a* and Fig. 324*b* show the wiring diagram complete of the ignition, starting, and lighting systems as installed on the 1916 and 1917 Maxwell cars. The heavy lines indicate the starting-system connections, while the light lines are the wires leading from the generator to the battery (through the regulator and cut-out), and the various connections for the ignition and the lamps. They show very plainly, upon tracing them out, the relation of the regulator and cut-out to the generator and the battery, as well as the method of dividing the six cells of the battery into two units for lighting service, and the coupling of all the cells in series for starting. It will be noted also that the storage battery is not utilized for ignition, as the starting switch closes the circuit of a dry battery of four cells for ignition when starting the engine. As the starting switch automatically opens this circuit when released, there is no danger of this battery being inadvertently left in circuit.

At the upper left-hand corner of the diagram, complete details of the ignition circuit and of the magneto itself are shown. The magneto (Simms) is of the true high-tension type, having primary and secondary windings on the armature core, as well as a condenser incorporated in it. As this sketch shows not only the relation of high-tension type of magneto to the plugs but also that of the essential parts of the magneto, as well as the relation of the ignition system to the starting and lighting systems through the combination starting and ignition switch, it will repay close study. The number of wires makes it appear as if this were a two-wire system, but upon noting the ground connections at the various terminals it will be evident that it is not.

Instructions. The Simms-Huff system as above described is standard equipment on the Maxwell cars. The combination cut-out and regulator is mounted on the rear of the dash panel carrying the ammeter and switch. It consists of two distinct devices, the cut-out serving the usual purpose of protecting the battery when the generator voltage drops, and the regulator limiting the current output of the dynamo as the engine speed increases. In connection

with it a special regulator switch is provided. This is located on the right side of the dash panel and has two positions, HIGH and LOW, the latter inserting additional resistance in the field circuit of the dynamo to further limit its output when the car is driven steadily at high speed on long runs. This switch is kept in the HIGH position for all ordinary driving and only shifted to LOW as above mentioned.

Failure of Cut-Out or of Regulator. Should the ammeter pointer go to the limit of its travel on the *discharge* side, this indicates that the cut-out contact points have failed to release on the slowing down of the generator. The latter also will continue to run as a motor after the engine is stopped. Disconnect the two wires from the terminals on the generator and wrap them with friction tape to prevent their coming in contact with any metal parts of the car. Clean and true up contact points as outlined in previous instructions. An unusually high reading on the *charge* side of the ammeter will indicate a failure of the regulator to work. If an inspection shows no sign of broken or crossed wires, loose connections, or other obvious trouble, the manufacturers recommend that the unit be sent to them. In the case of the owner, it is recommended that no attempt be made to correct faults in the cut-out or in the regulator, but that it be referred to the maker of the device or to the nearest service station.

Generator Tests. To determine whether a short-circuit or a ground exists in the brush holder, pull up all the brushes and with the aid of the lamp-test set, test by applying one end to the frame and the other to the main terminal post. The lamp will light if there is a short-circuit or a ground between the brush holder and the frame. A similar test may be made for the armature by pulling up all the brushes (or heavy paper may be inserted between them and the commutator) and placing one point on the commutator and the other on the shaft. The lighting of the lamp will indicate that the armature is grounded. In all tests of this nature where the lamp does not light at the first contact, it should not be taken for granted at once that there is no fault. Touch various parts of both members on clean bright metal. See that the points of the test set are clean, that the lamp filament has not been broken, and that the lamp itself has not become unscrewed sufficiently to break the circuit between it and

the socket. A good rule is always to test the lamp itself first; sometimes the connecting plug of the set is not properly screwed into the socket.

While the above test for the armature, if properly carried out, will show whether the latter is grounded or not, it will not give any indication of an internal short-circuit in the armature itself. To determine this, connect the shunt fields and run the unit idle as a motor, with the portable ammeter in the circuit, using the 30-ampere shunt. While running without any load the motor should not consume more than 7 amperes at 6 volts, i.e., using half the battery. Tests for grounds in the shunt field may be made with the lamp-test set, but to determine whether there is a short-circuit in the field, it is necessary to measure the resistance of its windings. If there is neither a short-circuit nor a ground in the field, the resistance of the windings should calculate approximately $6\frac{1}{2}$ ohms on units with serial numbers up to 27,000, and approximately 4.8 ohms on starters above this serial number.

The Simms-Huff is one of the very few, if not the only unit, that is belt-driven as a generator. Its normal output is 10 to 15 amperes; so when the dash ammeter shows any falling off in this rate, with the engine running at the proper speed to give the maximum charging current, the belt drive of the generator should be inspected. If the ammeter reading falls off as the engine speed increases, it is a certain indication that the belt is slipping and that the generator itself is not being driven fast enough. Adjust the tension of the belt and test again. If this does not increase the output to normal, inspect the commutator and brushes, brush connections and springs, etc. See that the brushes have not worn down too far, and if necessary, sand-in. Failing improvement from any of these expedients, inspect the regulator. This should not be adjusted to give more current until every other possible cause has been eliminated; and before making any change in the adjustment of the contacts, see if cleaning and truing them up will not remedy the trouble. If necessary to adjust, do so very carefully, as increasing the current output by this means will also increase the voltage, and if the voltage exceeds the normal by any substantial percentage, all the lamps will be burned out at once. Trouble in the electrical unit itself will be most likely to appear in the brush holder.

Whenever it is necessary to remove the front end plate over the commutator to inspect the commutator or the brushes, be sure that this plate *is put back the same way*, and not accidentally turned round a sixth of a revolution, which would cause the motor to run backward. There is a slot in the front end of this plate to permit the brush holder to be moved backward or forward so as to give the best brush setting as a generator and as a motor. On most of the Simms-Huff units, a chisel mark will be found on each side of the fiber insulator under the main terminal post, indicating the factory brush setting. Checking this brush setting should be one of the further tests undertaken before resorting to adjustment of the regulator. To do this, connect the portable ammeter in the charging circuit (30-ampere shunt) or, if one of these instruments is not available, the dash ammeter may be relied upon.

Run the engine at a speed high enough for the maximum normal output; loosen the brush holder and move very slowly backward and forward, meanwhile noting the effect on the reading of the ammeter; and mark the point at which the best output is obtained. To test as a motor, connect the ammeter in circuit with half of the battery and run idle. Move brush holder backward or forward to obtain best setting point, as shown by the ammeter reading, which, in this case, will be the minimum instead of the maximum. The unit should not draw more than 7 amperes when tested in this manner. If the best points for generating and running as a motor, as shown by these tests, are separated by any considerable distance, a compromise must be effected by placing the brush holder midway between them. If the dash ammeter does not appear to be correct, check it with the portable instrument or with another dash ammeter.

SPLITDORF SYSTEM

Twelve—Six=Volt; Single=Unit; Two=Wire

Dynamotor. Both windings are connected to the same commutator on the dynamotor, which is of the bipolar type.

Wiring Diagram. As the lamps are run on 6 volts, the 6-cell battery is connected as two units of 3 cells each for lighting, and these units are connected in series-parallel for charging, as the dynamotor produces current at 6 volts. The remaining details of the connections will be clear in the wiring diagram, Fig. 325.

Six-Volt; Two-Unit

Control. *Switch.* The starting switch is mounted on the starting motor. This switch automatically breaks the circuit as soon as the engine starts. The starting gear slides on spiral splines on the armature shaft, so that when the engine gear over-runs it, the starting gear is forced out of engagement. This gear is connected

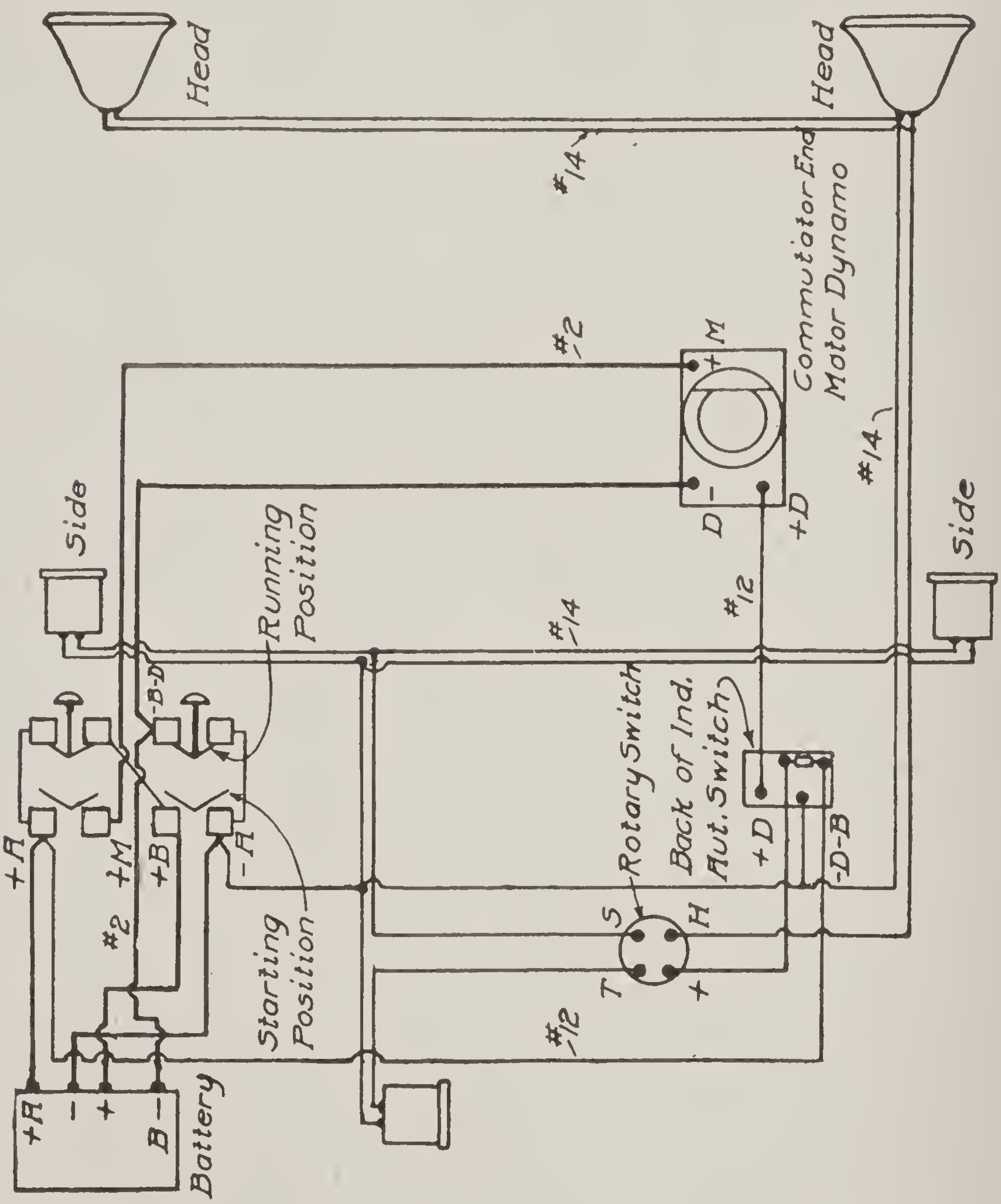


Fig. 325. Wiring Diagram of Splitdorf-Apelco Twelve in Six-Volt Single-Unit Two-Wire System

to a drive rod which also engages a switch rod, so that when the gear is forced out of mesh with the flywheel, it carries the switch rod with it and automatically opens the circuit. The switch contacts cannot stick, and no damage can result from holding down the switch pedal after the engine has started.

Regulation. On the earlier models, a vibrating regulator was built in the generator, as illustrated in the section on Constant-

Potential Generators, but in later models an external regulator combined with the battery cut-out is employed. This is a constant voltage control of the vibrating type, similar to that described in detail in connection with the Bijur system, i.e., an electromagnet operating two spring-mounted armatures carrying contacts.

Instructions. Should a discharge of 3 amperes or more be indicated on the ammeter when the engine is idle and all lights are off, this can be eliminated by slightly increasing the tension of the spring at the rear end of the cut-in armature.

Too great an increase in the tension of this spring will cause the cut-in, or charging point, to be raised too high, as indicated by the ammeter, which should be noted when making the adjustment.

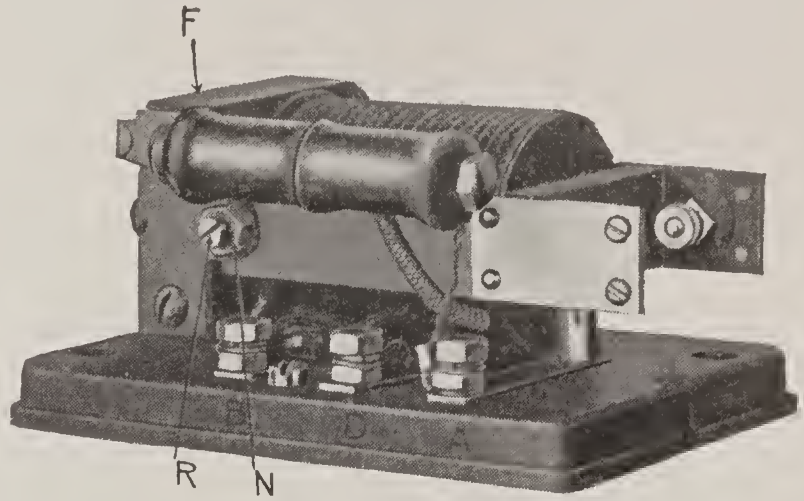


Fig. 326. Splitdorf VR Regulator
Courtesy of Splitdorf Electric Company, Newark, New Jersey

The voltage regulator as set at the factory is adjusted to limit the output of the generator to from 7 to 10 amperes. Should it be necessary to increase this for winter running or for any other reason, it may be done by increasing the tension of the spring armature. The amount of movement of the adjusting screw at the rear end of the armature that is necessary will be indicated by the reading of the ammeter. The passage of current at the regulating contacts, which are in constant vibration while the engine is running above a certain speed, tends to roughen them. In time this may affect the charging rate and cause the points to stick together, which will be indicated by the ammeter showing a permanent increase in the charging rate. If the latter becomes excessive, the cover of the regulator should be removed, and a thin dental file passed between the contacts on the stationary screw *R*, Fig. 326, and the movable contact on the regulating armature until both become smooth. In case it is necessary to remove the contact screw *R* for the purpose of smoothing its point, be sure to replace it at the same position, taking care that the ammeter reading does not exceed 7 to 10 amperes and that the lock-nut *N* is fastened securely. Under ordinary conditions, these con-

tacts should not require attention on an average oftener than once a year, but it would be well to examine them occasionally.

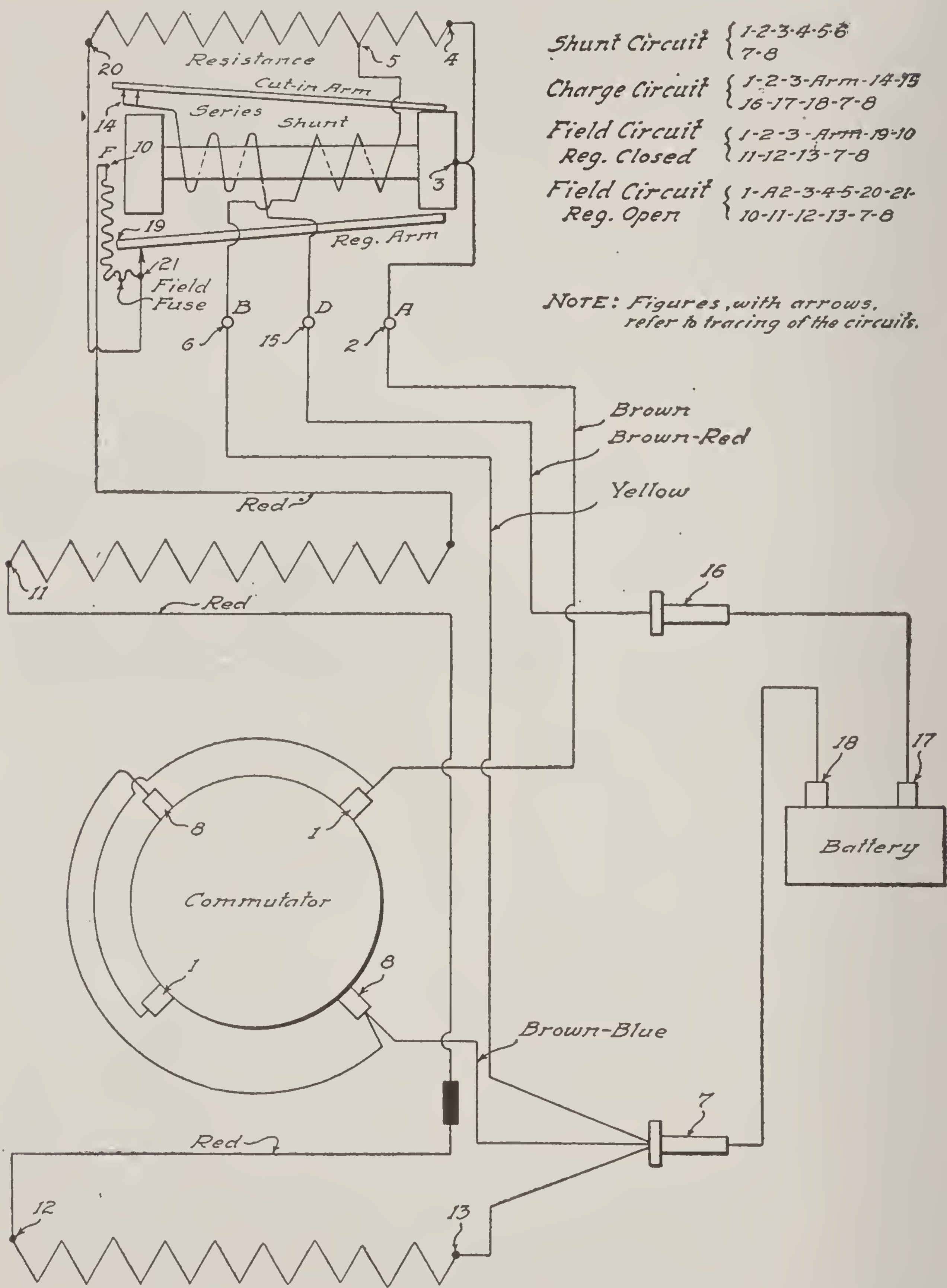


Fig. 327. Wiring Diagram of Splitdorf Lighting Generator and VR Regulator

By referring to Fig. 327, which is a diagram of the wiring of the generator and battery, the relation of these essentials to the regulator and cut-out are made clear. The field fuse shown on this diagram is

also indicated at *F* in Fig. 326. This fuse is a small piece of soft-alloy wire mounted between the post *F* and the contact-breaker. By referring to the wiring diagram, it will be noted that this fuse is in the shunt-field circuit, so that if it has been blown, the machine will not generate. It is designed to blow only at high speed with the battery off the line and the vibrator contact *R* stuck. In actual practice, the regulator cut-out is mounted directly on the generator itself. The colors mentioned alongside the different wires are for purposes of identification so that there will be no mistakes in making the various connections.

Starting Motor. The starting motor is of the series-wound type and is similar in design to the generator. It is supplied with a Bendix drive as shown in Fig. 328.

The starting motor has been designed so that when the operator pushes a foot pedal or pulls a lever, a gear is carried into mesh

Fig. 328. Splitdorf SU Starting Motor
Courtesy of Splitdorf Electric Company, Newark, New Jersey

with a ring gear on the flywheel, and when the engagement is made, current is supplied to the motor. The gear is movably carried on the armature shaft by spiral splines. These splines tend to hold the gear in mesh while the engine is being cranked. As soon as the engine picks up, it turns faster than the motor pinion which is operated with the flywheel, and on account of the spiral splines the pinion is forced out of mesh with the gear on the flywheel. The gear, while being "drivingly" mounted on the armature shaft, is also mechanically connected to a connecting rod, which, as will be noted from the illustration, protrudes from the commutator end of the motor.

The feature of this construction is, that no matter how long the operator may hold his foot on the starting pedal, the current is broken when the engine starts, as in the manner previously described. The

amount of current actually required for turning over the engine is thus controlled by the engine itself, and on account of the positive connection between one element of the switch and the starting gear, all possibility of the jaws of the starting switch sticking is eliminated.

Instructions. Apart from the special adjustments of the starting switch, as mentioned in the description of its operation, the instructions for maintenance are the same as those for other systems. In case this switch does not operate properly, the sequence of operations as mentioned should be checked up, and the distances given verified. In case these distances have become greater through wear, they should be adjusted. To replace the brushes, remove the cover strap over the commutator end of the unit, either generator or motor, put the two screws holding the rocker disc in place, disconnect the brush leads, and withdraw the brushes from the holders. It is important that the brushes slide freely in the holders and that the brush-lead terminals are clean and bright before replacing the terminal screws. See that the springs rest fairly on the ends of the brushes and that their tension has not weakened. Follow instructions given in connection with other systems for care of the commutator.

Failure of Engine to Start. When the starting motor cranks the engine after the starting pedal is depressed but fails to start the engine after a reasonable time, release the starting pedal and ascertain the cause, which may be due to the following: Ignition off, lack of fuel, fuel supply choked, cylinders needing priming due to weather conditions, or cylinders flooded from too much priming.

Should the starting motor fail to crank the engine when the starting pedal is fully depressed, there is a possibility that the battery is run down (which condition will be indicated by an excessive dimming of the lights), that there is a loose connection in the starting circuit, or that the starting switch is not making proper contact. The various tests previously given will probably take care of all these conditions.

Oiling of Starting Motor. The starting motor should be oiled once every 500 miles with any medium high-grade oil by applying oil to the cups, switch rods, guide rods, and pawl; also on the compensating device. Starting motors equipped with the Bendix drive are fitted with oil cups at each end of the unit.

U.S.L. SYSTEM

Twenty-Four—Twelve-Volt, and Twelve—Six-Volt; Single-Unit; Two-Wire

Variations. The 24—12-volt signifies that the starting voltage is 24 and the generating voltage 12, the battery of twelve cells being divided into two groups of six each in series-parallel for charging, while 12—6 signifies that the starting voltage is 12 and the generating voltage 6, the 6-cell battery being divided in the same manner.

The foregoing systems will be found on cars prior to, and including, 1915 models. For 1916 and 1917 models, a 12—12-volt system of the same single-unit two-wire type is standard. In this system the complete battery is used for the lighting as well as the starting, so that charging, lighting, and starting are all at the same voltage, using the complete battery of 6 cells for both of the former.

Generator-Starting Motor. The machine is multipolar (either six or eight poles) and is designed to take the place of the flywheel of

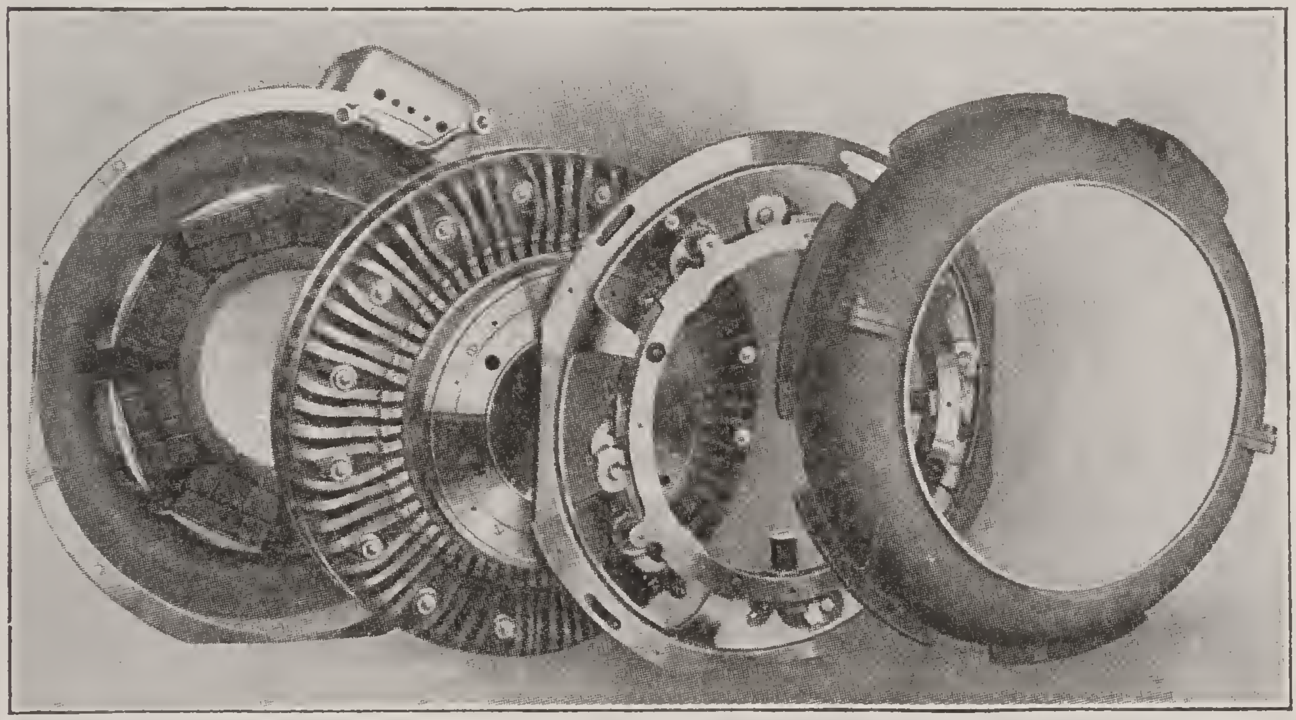


Fig. 329. Details of U.S.L. Flywheel Type Dynamotor with Outside Armature
Courtesy of U. S. Light and Heat Corporation, Niagara Falls, New York

the engine. All but the 12—6-volt equipments are made with an outside armature, Fig. 329, i.e., the armature revolving outside of the field poles which it encloses; and the 12—6-volt with an inside armature, Fig. 330. As the armature is mounted directly on the end of the crankshaft, the drive is direct at engine speed whether charging or starting.

One of the advantages of this type of machine, owing to its large size, is its ability to generate an amount of current far in excess of any ordinary requirement. This permits the employment in the inher-

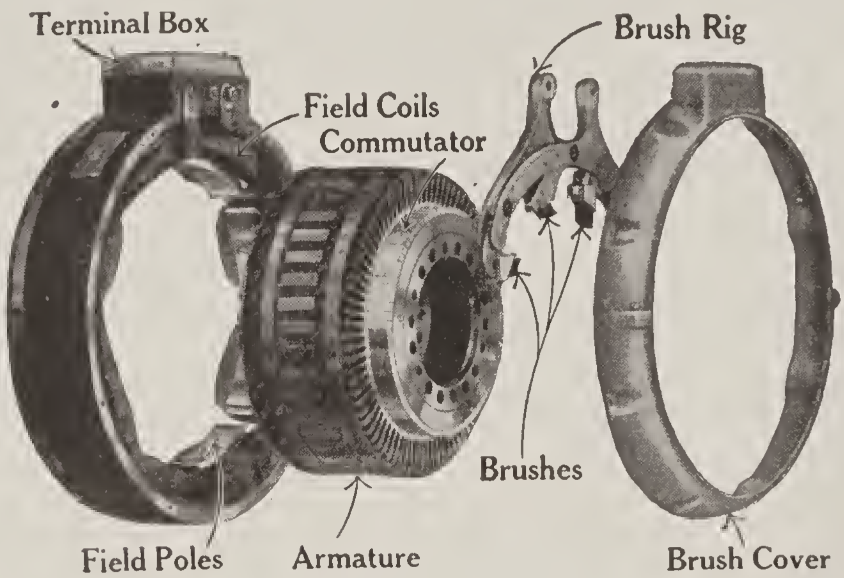


Fig. 330. U.S.L. Inside Armature Type Dynamotor (External Regulator)

ently regulated type of only three brushes, Fig. 331, when the unit is running as a generator, while all the brushes are employed when it operates as a starting motor. In the types equipped with an external regulator, all the brushes are employed for generating as well as for starting.

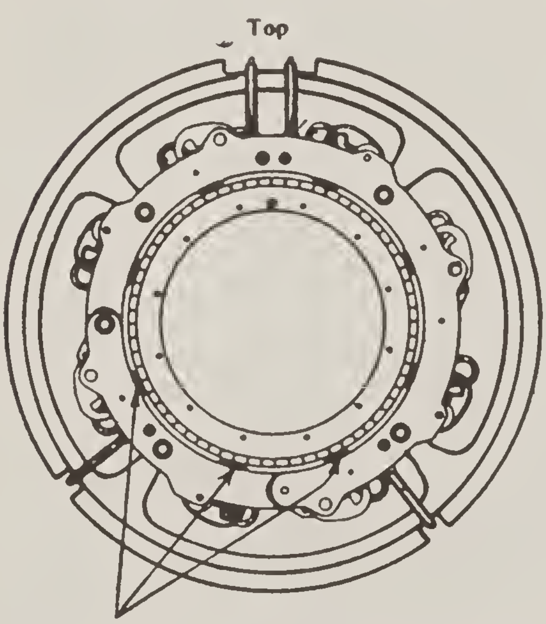


Fig. 331. Location of Generating Brushes in U.S.L. Dynamotor

Regulation. The 24—12-volt unit in the U.S.L. system is made with two types of regulation, one type using an external regulator, which is usually mounted on the dash, and the other of the inherent type. The 12—6-volt type has an external regulator. These two types may be distinguished by the presence of the regulator in the charging circuit, which, however, must not be confused with the automatic switch, or battery cut-out, which is only employed on the inherently regulated type. The details of the regulator are shown in Fig. 332, and it will be noted that the regulator also incorporates the battery cut-out as well as an indicating pointer which shows whether the regulator is working properly or not. In operation, the regulator cuts into the generator field

circuit a variable resistance consisting of an adjustable carbon pile. The connections of the regulator are shown in the wiring diagrams.

The regulation of the U.S.L. inherent type is accomplished by the combination of a Gramme ring armature, a special arrangement of connections and of the field windings, and the use of only a part of the armature and fields for generating. This method is, of course, special on this make and could not be used on other types of construction. The regulation obtained is based on armature reaction and is similar to that resulting from the third-brush method, but the machine

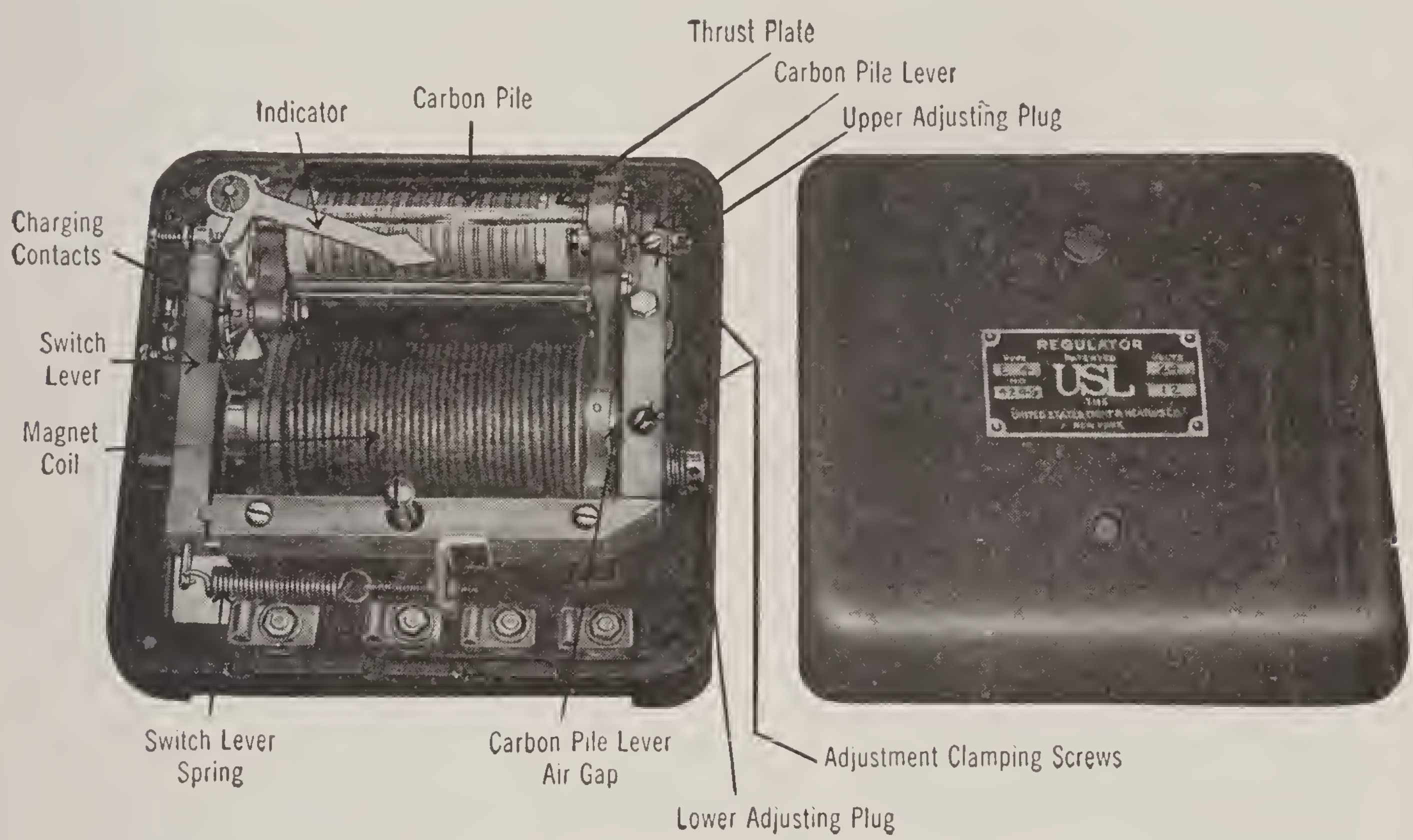


Fig. 332. External Regulator of the U.S.L. System
Courtesy of U. S. Light and Heat Corporation, Niagara Falls, New York

reaches its maximum output at a lower speed than would be possible with the third-brush method and without the employment of a special brush for the purpose.

Instruments and Protective Devices. In addition to the indicator, which is combined with the external regulator in the U.S.L. type, an ammeter is also employed to show the rate of charge and discharge.

Two fuses, mounted in clips on the base which holds the battery cut-out, or automatic switch, protect all the circuits. The smaller of these is a 6-ampere fuse and is in the field circuit of the generator, while the larger is a 30-ampere switch and is in the generator charging circuit. This applies only to those inherently regulated equipments fitted with a special type of automatic switch.

Wiring Diagrams. Figs. 333, 334, and 335 show the standard wiring diagrams of the three types mentioned, being, respectively, the 24—12-volt externally regulated type, the 12—6-volt external regulator and internal-armature type, and the 24—12-volt inherently regulated type. In the diagram proper of each of the 24—12-volt types is indicated the layout for using 7-volt lamps, while the extra diagram at the side shows the method of connecting for 14-volt lamps. The "touring switch" shown on the first two diagrams is a hand-operated switch in the charging circuit and is designed to prevent overcharging of the battery when on long day runs. The inherently regulated type requires very little field current, and on most of these the touring switch is of the miniature push-button type, like a lighting switch.

Instructions. *Touring Switch.* On the types equipped with the touring switch, this enables the driver to control the charge. Pulling out the button closes the switch and permits the generator to charge the battery when the engine reaches the proper speed; pushing it in opens the circuit. This switch must always be closed before starting the engine, and it must be kept closed whenever the lights are on and also under average city driving conditions where stops are frequent and but little driving is done at speed. When touring, the switch should be closed for an hour or two and then allowed to remain open during the remainder of the day, as this is sufficient to keep the battery charged, and there is no need for further charging until the lamps are lighted. The best indication of the necessity for opening the touring switch is the state of charge as shown by the hydrometer. The driver should not start on a long day's run with the battery almost fully charged, without first opening the touring switch, as the unnecessary charging will overheat the battery. This switch should be inspected at least once a season. Push in the button to open the circuits, remove the screw at the back and take off the cover. The switch fingers should be bright and make good contact with the contact block; if they do not do so, remove and clean them, as well as the contact pieces on the block. Do not allow tools or other metal to come in contact with the switch parts during the operation, for even though the switch is open, a short-circuit may result; then one of the fuses will blow. In replacing the fingers, bend sufficiently to make good firm contact.

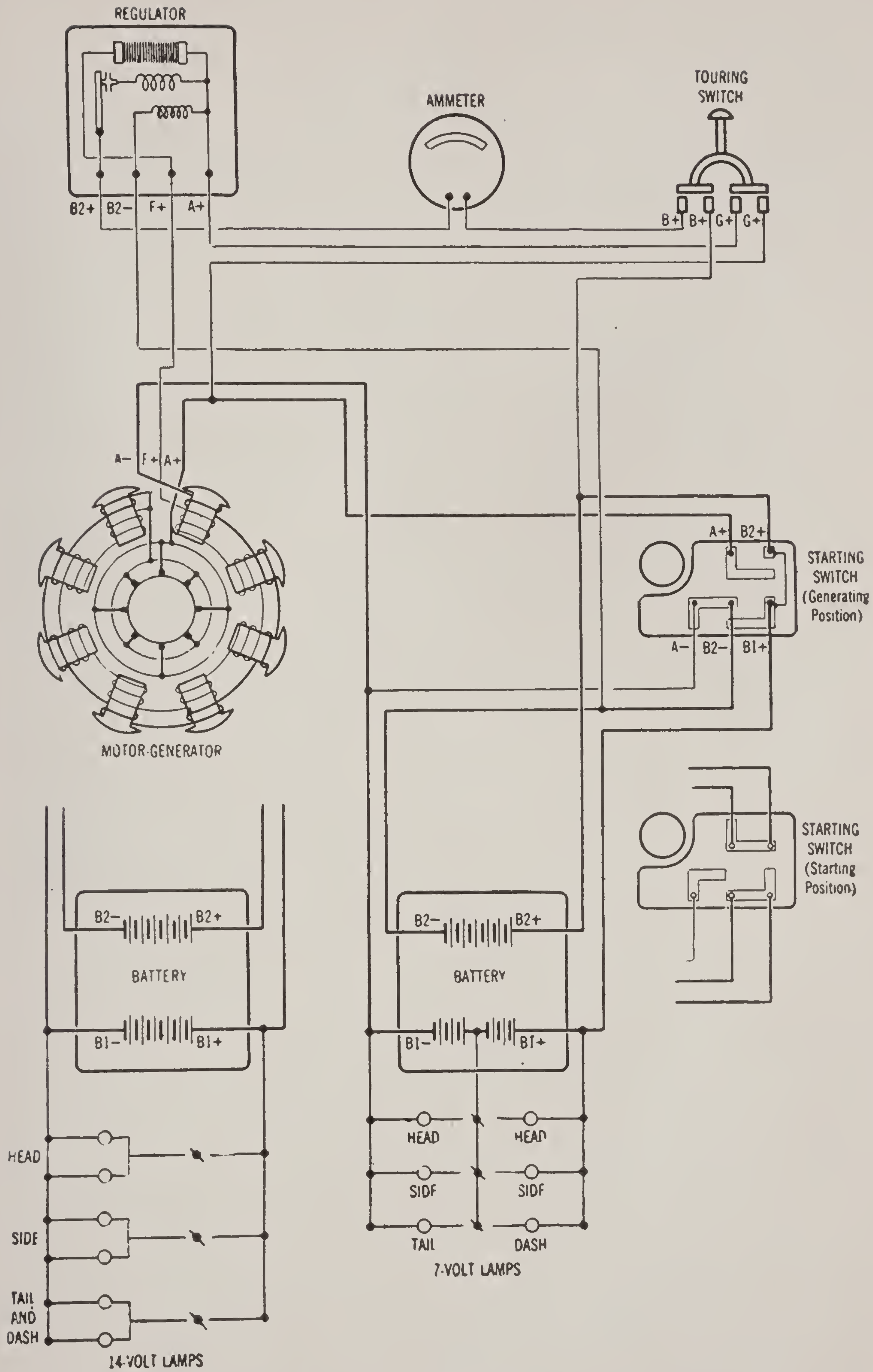


Fig. 333. Wiring Diagram for 24—12-Volt Regulator Type, U.S.L. System

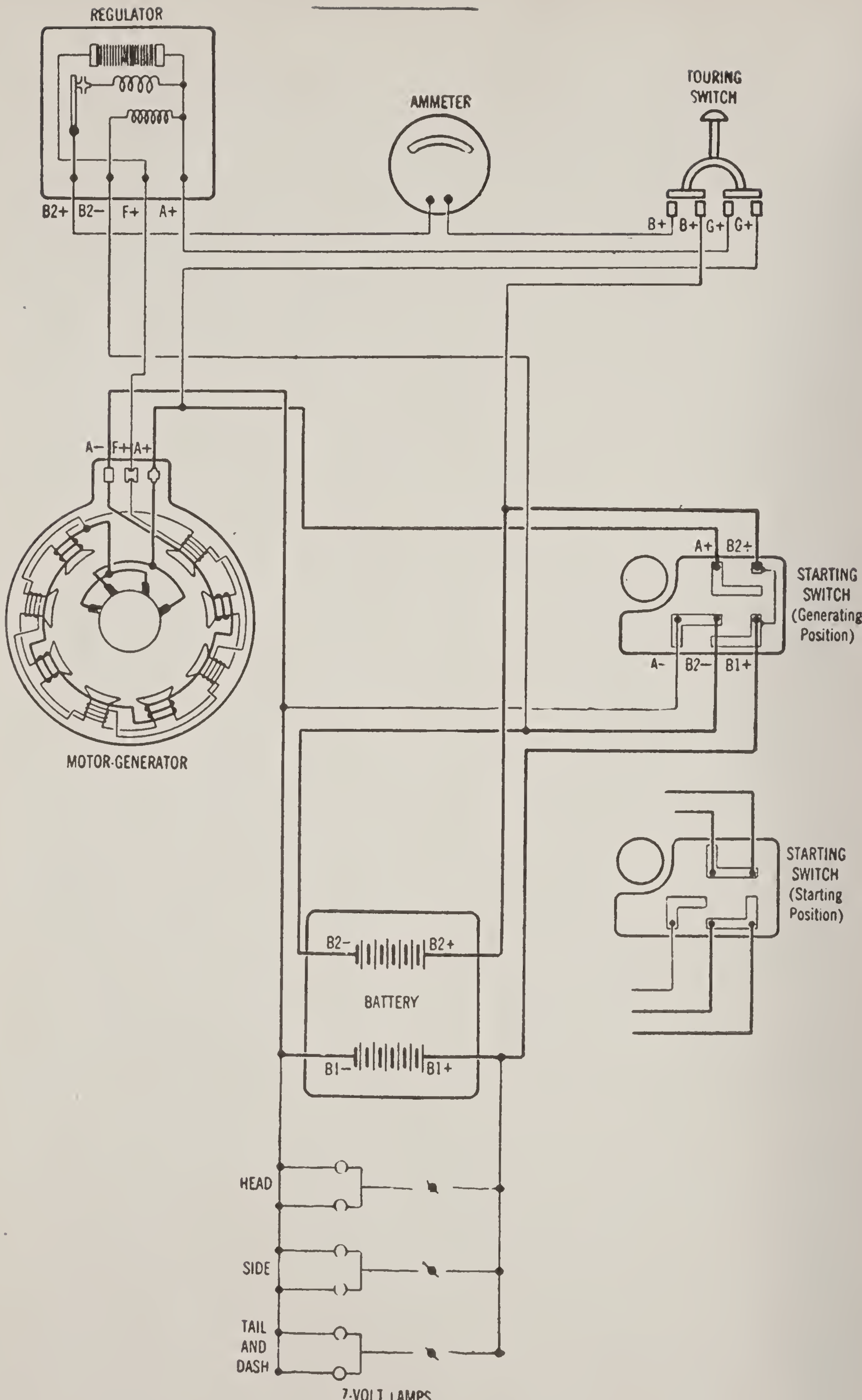


Fig. 334. Wiring Diagram for 12—6-Volt External Regulator Type, U.S.L. System

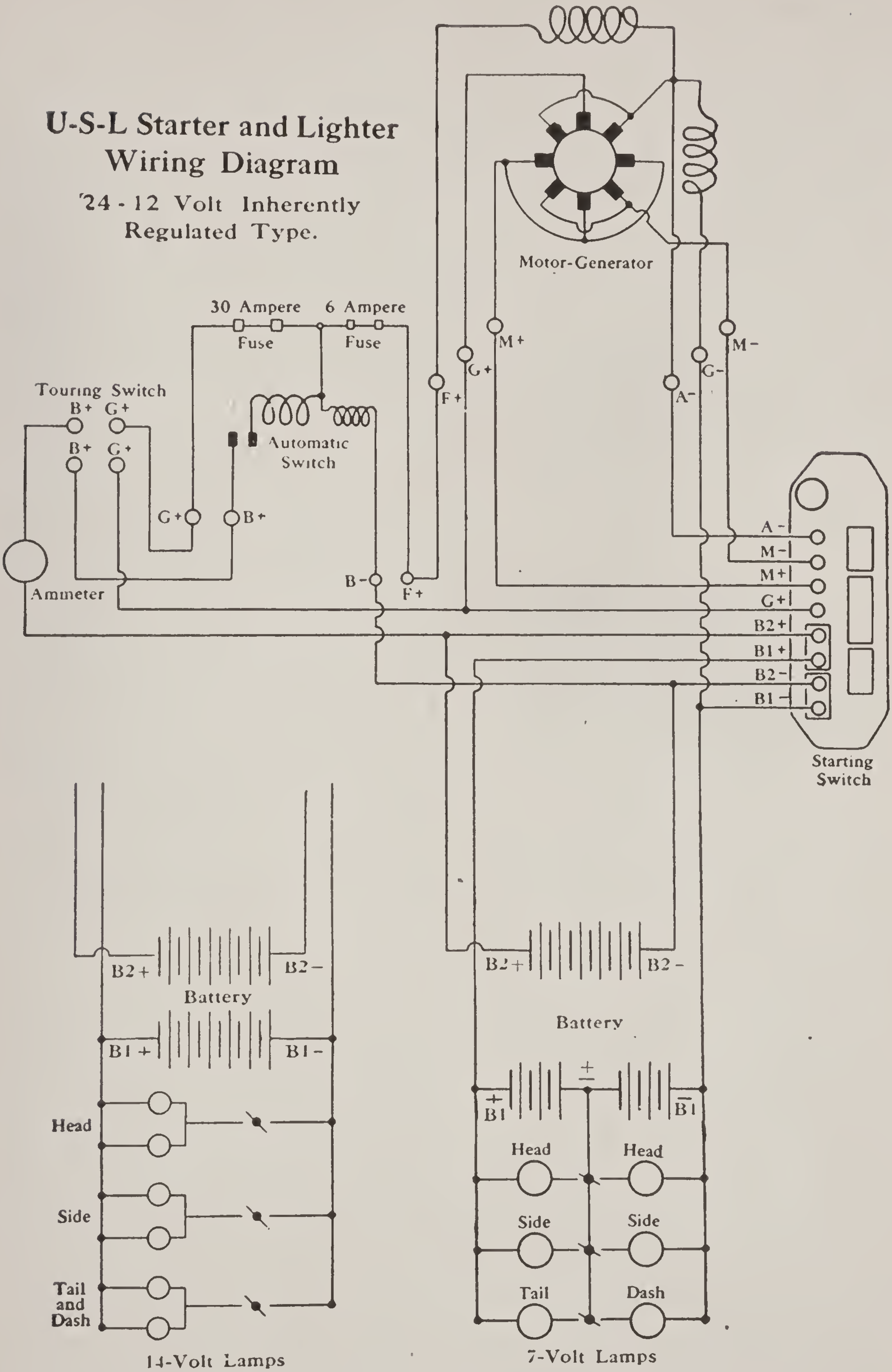


Fig. 335. Wiring Diagram for 24—12-Volt Inherently Regulated Type, U.S.L. System

Starting Switch. The starting switch is filled with oil, and this should be renewed once a year. To do this, the switch must be disconnected, and the screws *A*, Fig. 336, removed; in case the box sticks, insert a screwdriver point between the top of the box and the bottom of the frame and pry loose. To guard against the switch dropping when these screws are removed, hold the hand beneath it while taking them out. Before attempting to remove the switch, disconnect the positive battery connections *B1+* and *B2+* at the battery as shown in Fig. 335. These are the two main terminals in the center. It is unnecessary to tape them, as a short-circuit cannot occur. Pour out the old oil, clean out thoroughly with gasoline, allow to dry, and refill with transformer oil or light motor oil to the proper level with the switch box standing plumb. The proper height on the Type E-2 or E-3 box is $1\frac{5}{8}$ inches, on E-4 box $2\frac{3}{4}$ inches. Before putting in the new oil, however, the drum and finger contacts should be examined, and, if pitted or dirty, should be cleaned with a fine file. Make sure that all fingers bear firmly against the drum so as to make good contact; if they do not, remove and bend them slightly to insure this. If the starting switch is abused in operation, or if improper oil containing water or other impurities be used, the contacts will burn and fail to make good electrical connection. The switch box is the only place in the system requiring oil.

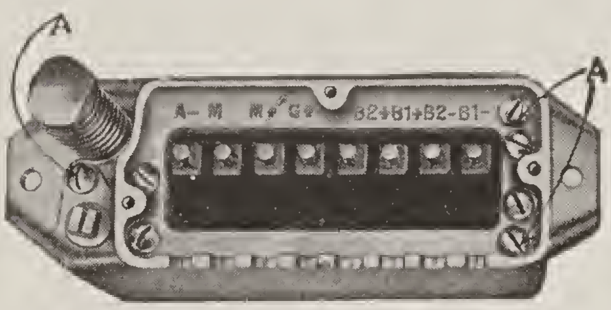


Fig. 336. U.S.L. Oil-Filled Starting Switch

Brush Pressures. There is only one adjustment on the generator, viz, the tension of the brush fingers. The brushes should fit freely in their holders so as to transmit the full pressure of the spring against the commutator. The adjustment as made at the factory should not need correction under one or two years of service. Pressures required on the various machines are as follows: for Type E-12 external regulator, $1\frac{3}{4}$ pounds on each brush; $1\frac{1}{4}$ pounds on brushes of all other external-regulator machines; $1\frac{3}{4}$ pounds on each of the three lowest brushes on the inherently regulated type, these being the only brushes used in generating the charging current; $1\frac{1}{4}$ pounds on each of the remaining brushes of the inherently regulated generator. Keep commutator clean, as the chief cause of

failure of the inherently regulated type is an excess of oil or dirt or both accumulating on it.

Radial and Angular Brushes. The brushes employed are of two types—radial and angular. Radial brushes are used on external-regulator type generators other than those having "Type E-49" on the name plate; angular brushes are used on Type E-49 and all inherently regulated generators. Each radial brush should bear squarely against that side of its holder toward which the commutator rotates. Each angular brush should bear squarely against that side of its pocket away from which the commutator rotates. To sand-in old brushes or fit new brushes properly, insert a strip of No. 00 sandpaper (never use emery, paper, or cloth), between the commutator and the brush, press down on top of brush and draw sandpaper under it, Fig. 337. If the brush is *radial,* draw the sandpaper in the direction of commutator rotation; if *angular,* draw the sandpaper in the direction opposite to that of commutator rotation. No oil is needed on the commutator as the brushes themselves contain all the lubricant necessary. Fine sandpaper, as mentioned above, may be used for cleaning the commutator when necessary, the engine being allowed to turn over slowly during the operation.

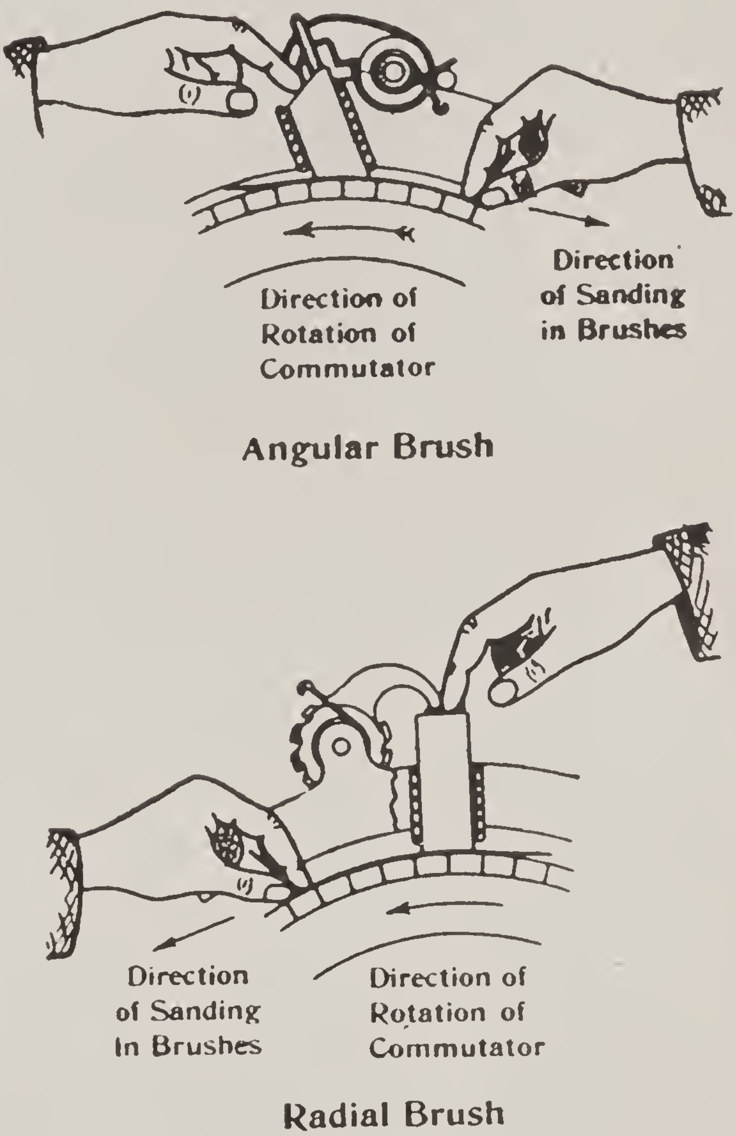


Fig. 337. Methods of Sanding-In Brushes on Dynamotor

External Regulator. Should the automatic-switch (cut-out) member of the regulator remain closed with the engine stopped, start the engine at once, and the switch lever should open. If it does not, remove the regulator cover (with the engine running) and

pull the lever open by hand. When the switch lever is correctly set, a slight discharge will be noted on the ammeter the moment the switch lever opens. This discharge reading should not exceed 4 amperes; if in excess of this, increase the tension of the switch-lever spring by releasing the lock nut on the left side of the plate and turning up on the nut at the right until the proper adjustment is secured, then retighten the lock nut. The indicating pointer is moved by the switch lever in closing, and when it appears in its upper position through the sight glass on the cover, the battery is charging; when the switch lever opens, the pointer drops against its stop by gravity.

When the battery shows a lack of capacity, the battery itself and all connections and fuses being in good condition, note the amount of charging current indicated by the ammeter. If the maximum current (external-regulator type) shown by the ammeter does not exceed 10 to 12 amperes at full engine speed after the engine has been running for fifteen minutes, see that the brushes and commutator are in good condition—wipe off the commutator with a dry cloth, and, if necessary, sand-in the brushes to a good seat. If this does not increase the generator output as shown by the ammeter, test the latter as already noted, i.e., see whether the pointer is binding and, if not, check with the portable testing instrument or another ammeter of the dash type. Should none of these remedies correct the fault, *screw in* the lower adjusting plug of the carbon-pile lever slowly, noting the effect on the ammeter reading as the adjustment is made.

With the external regulator, the charging current should not exceed 18 amperes at the highest engine speed. If, at any time, the ammeter shows a higher reading than this, *screw out* the lower adjusting plug of the carbon-pile lever slowly to decrease the current, stopping when the indication does not go above 18 amperes at full speed.

After making this adjustment of the lower plug, make sure that the carbon-pile lever air gap does not exceed $\frac{1}{8}$ inch, and is not less than $\frac{3}{32}$ inch when the engine is stopped. If the gap is too small the switch lever will vibrate rapidly at high engine speeds. When necessary to adjust this gap, screw the upper adjusting plug in or out, but, after doing so, the current output must be checked and adjusted by means of the lower adjusting plug. Always tighten

the adjustment clamping screws after setting either of the adjusting plugs.

Testing Carbon Pile. If the automatic-switch unit of the generator does not cut in with the engine running at speed equivalent to 10 to 14 miles per hour, test the carbon pile by short-circuiting the terminals $F+$ and $A+$ of the generator with the blade of a screwdriver. Speed up the engine slowly and note whether the generator cuts in much sooner than when the terminals are not short-circuited. Do not run the engine at high speed, nor for any length of time with the terminals short-circuited, as an excessive amount of current would be generated. If the generator does cut in much earlier with the terminals short-circuited than without this, the carbon pile needs cleaning. Should the generator not cut in earlier or should it fail to operate altogether, when the carbon pile is short-circuited the trouble is probably in the brushes of the generator or in the touring switch.

To clean the carbon pile, proceed as follows: Unscrew the plug at the upper end of the glass rod and remove the rod; if any of the discs are pitted or burned, rub them together or against a smooth board to make them smooth and flat. Remove the end carbons and clean the brass plates with fine sandpaper, if necessary. In replacing end carbons, make sure that they fit firmly against the brass end plates and that the screw heads do not project beyond the faces of the carbon discs. After reassembling the carbon pile, the regulator will need adjustment for current output, as previously noted.

If for any reason it becomes necessary to disconnect the battery, either open the touring switch and block it open so that it cannot be closed accidentally if the car is to be run, or disconnect and tape the right-hand regulator terminal $A+$. Otherwise, the machine will be damaged by operating.

Battery Cut-Out. Should either of the fuses mounted on the automatic switch of the inherently regulated type blow, immediately open the touring switch. A loose connection or a short-circuit is probably the cause, and the touring switch should not be closed again until the cause has been located.

Ammeter. The ammeter should be checked at least once a year by comparing it with a standard instrument, such as the portable outfit mentioned previously, or any other suitable low-reading ammeter

of known accuracy. To do this, disconnect the positive wire from the ammeter on the dash and connect it to the positive terminal of the standard ammeter used for testing; then connect a wire between

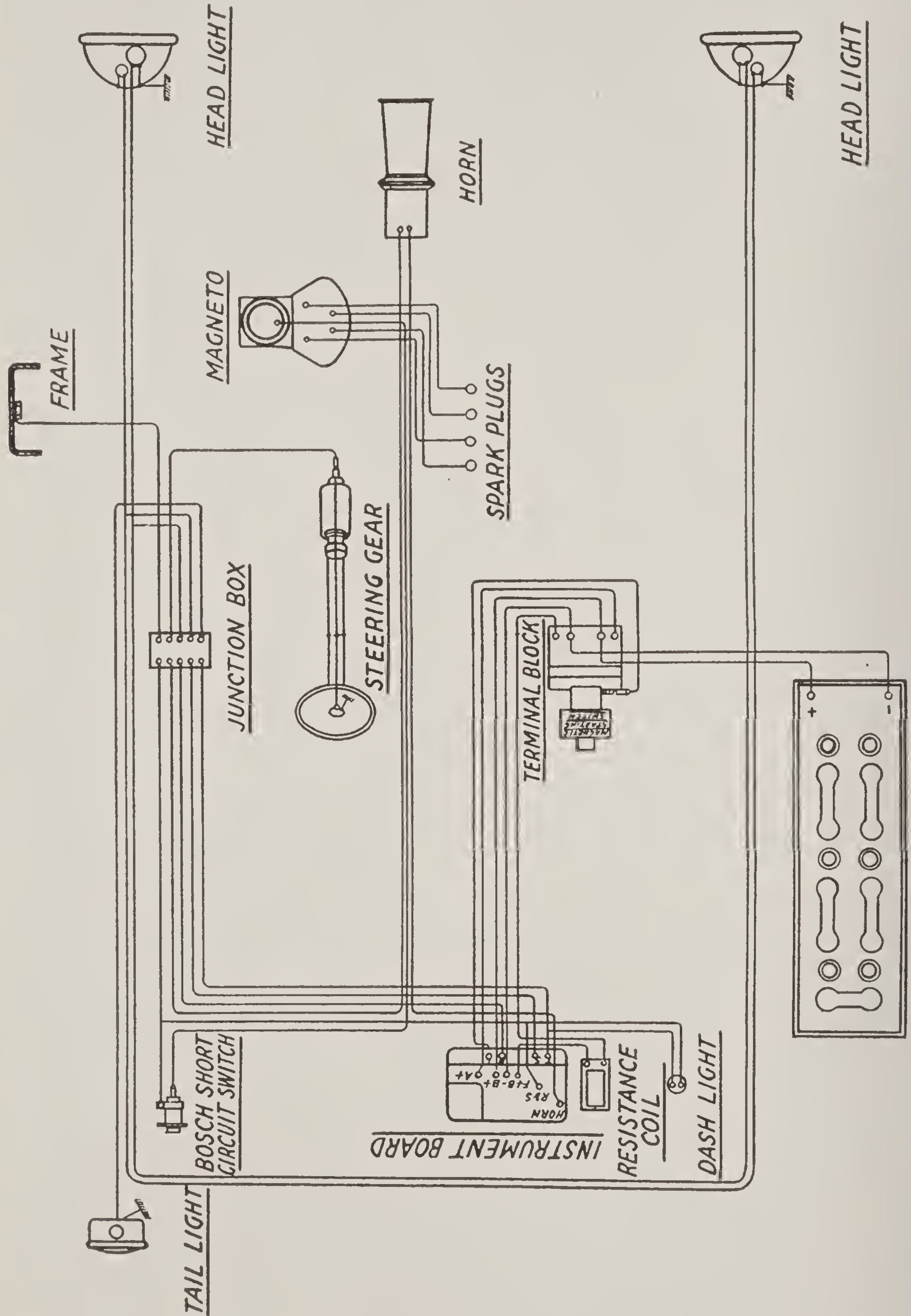


Fig. 338. Wiring Diagram of U.S.L. System on 1917 Mercer Cars

the negative terminal of the standard ammeter and the positive terminal of the dash ammeter. With the engine running at various speeds, take simultaneous readings of both instruments; any differ-

ence between the two should be taken into consideration thereafter when reading the dash ammeter. Unless a test of this kind is carried out, the battery may be receiving either an insufficient or an excessive charge while the ammeter indicates the proper amount.

U.S.L. 12=Volt System. The U.S.L. 12-volt system generates and starts at 12 volts and is standard on the 1916 and 1917 models of the Mercer, Fig. 338. It differs from the other systems in having a magnetically operated starting switch and a centralized control unit, which incorporates all the controlling devices of the entire system, the cut-out, the ammeter, fuse blocks for generator and lighting circuits, starting switch, touring switch, head, side, and tail-light switches, all of which are operated by push buttons. All of these switch buttons, as well as the fuses, are locked in place, while the buttons may be locked in any desired combination of positions.

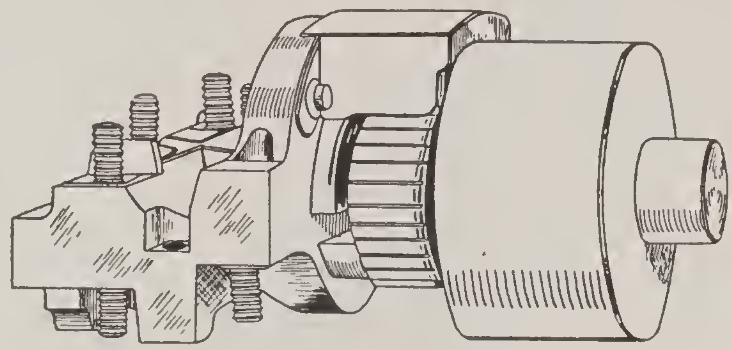


Fig. 339. U.S.L. Type E-14 Starting Switch

Starting Switch. This is of the magnetically operated type and is mounted on the top of the field-mounting frame. It operates by means of a solenoid and plunger, as illustrated in Fig. 339. Control is by means of a spring push button on the control unit marked "start", Fig. 340. When this button is pushed in, it energizes the solenoid of the starting switch, which causes the plunger to close the contacts. Releasing the button on the control unit breaks the circuit, and the switch itself is then opened automatically by a self-contained spring. With this method of control, the current is only on as long as the starting button is held in.

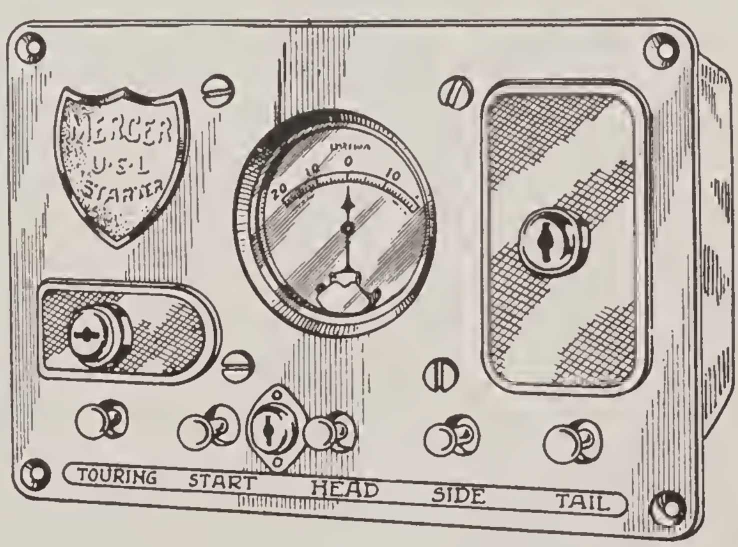


Fig. 340. U.S.L. Control Panel as Mounted on Dash of Mercer Cars

Fuse Blocks. There are two of these, the smaller, illustrated in Fig. 341, being the generator fuse block. This contains only two

fuses, a large one *9* of 30-ampere capacity in the generator-battery charging circuit, and a smaller one *8* of 5-ampere capacity in the generator shunt-field circuit. Should either fuse blow, immediately push in the touring-switch button, as a short-circuit or an open or a loose connection is probably the cause. After locating the trouble, remove the generator fuse block from the instrument board. To do this, unlock the knob, press it inward, and turn $\frac{1}{4}$ revolution to the right or to the left. Replace with spare fuses carried in the light fuse block, return the generator fuse block to its original position, and lock.

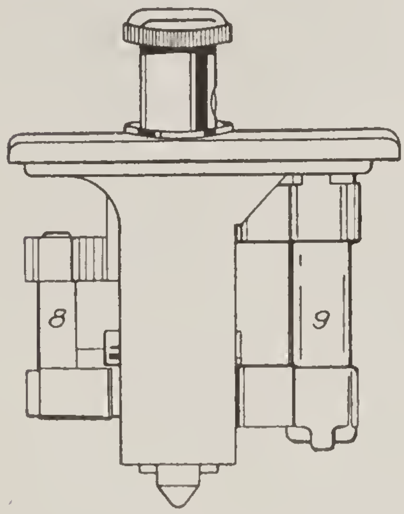


Fig. 341. U.S.L. Generator Fuse Block

The light fuse block, which is shown in Fig. 342, carries a total of seven fuses, of which four are in active use, while the remaining three are spare fuses for use in replacing blown fuses. On the right-side view of this fuse block there appear two large fuses *6* and *7*. Fuse *7* is a protecting link in the ground-return wire of the lighting and horn circuits. The small fuse *5* is of 10-ampere capacity and, together with

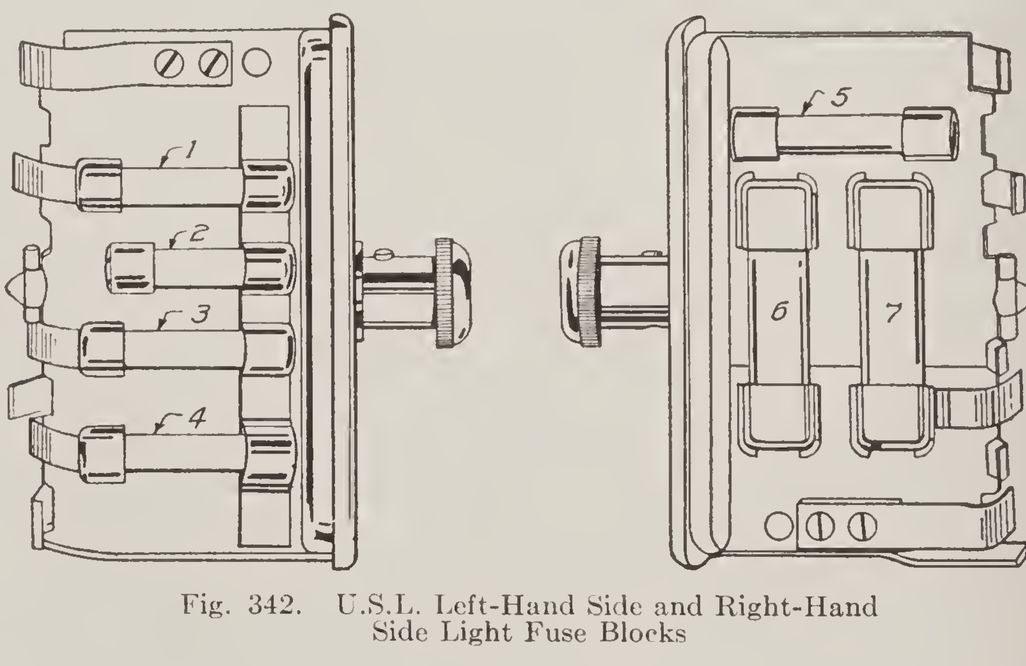


Fig. 342. U.S.L. Left-Hand Side and Right-Hand Side Light Fuse Blocks

fuse *6* of 30-ampere capacity, is a spare fuse for emergency use. On the left side of the block are three active fuses *1*, *3*, and *4* of 10-ampere capacity; and one spare fuse *2* of 5-ampere capacity. Fuse *1* is in the horn circuit, fuse *3* in the headlight circuit, and fuse *4* is common to the tail-, dash-, and side-light circuits. Should any of the fuses on this block blow, the trouble is probably a short-circuit on the frame of the car which should be remedied before the fuse is replaced. Instructions

for the use of the touring switch in this system are the same as previously given.

U.S. Nelson System. This type has been specially designed for the Nelson car, which first appeared in 1917, and it differs radically from those already described in that it is carried on the forward end of the engine crankshaft instead of at the rear. The brushes bear on the inside face of the commutator and may be reached through three openings in the armature support. To clean the commutator in this type, it is necessary to turn the armature so that three of the six brushes appear opposite these openings. Fold a small piece of sandpaper into a square over one of the brushes and allow the engine to turn over for a few minutes. Stop the engine and remove the sandpaper through one of the openings. The engine carries a flywheel at the rear, as usual, and this provision of flywheel weight at both ends of the crankshaft is said to minimize vibration almost to the vanishing point while making possible extremely high speeds.

WAGNER SYSTEM

Twelve-Volt; Single-Unit; Two-Wire (Early Model)

Dynamotor. The bipolar-type dynamotor has both the series and the shunt-windings, i.e., of generator and motor, connected to the same commutator. It is driven direct as a generator, and through a special planetary gear when operating as a starting motor.

Regulation. The regulation is of the inherent type, utilizing the generator winding to weaken the field with increase in speed, i.e., a bucking coil.

Wiring Diagram. *Single-Unit Type.* The left side of the lower half of the diagram, Fig. 343, illustrates the connections when the unit is being used as a starter, as indicated by the arrow showing the direction of rotation of the armature. Those at the right are the running connections, the armature then rotating in the reverse direction and generating current to charge the battery.

Control; Transmission. *Switch.* This is a special type of drum switch mounted directly on the dynamotor on the same base with the battery cut-out. As shown in Fig. 344, when the lever Q is thrown to the left for starting, it also serves to tighten the brake band on the planetary gear. When moved in the opposite direction, it releases this brake, and another set of contacts on the drum of

the switch connect the generator for charging. Fig. 345 shows the details of this switch: A, B, and C are the contacts on the starting side, while H, G, and F are the running-position contacts, as shown in Fig. 343. The segments E and L on the drum contact with

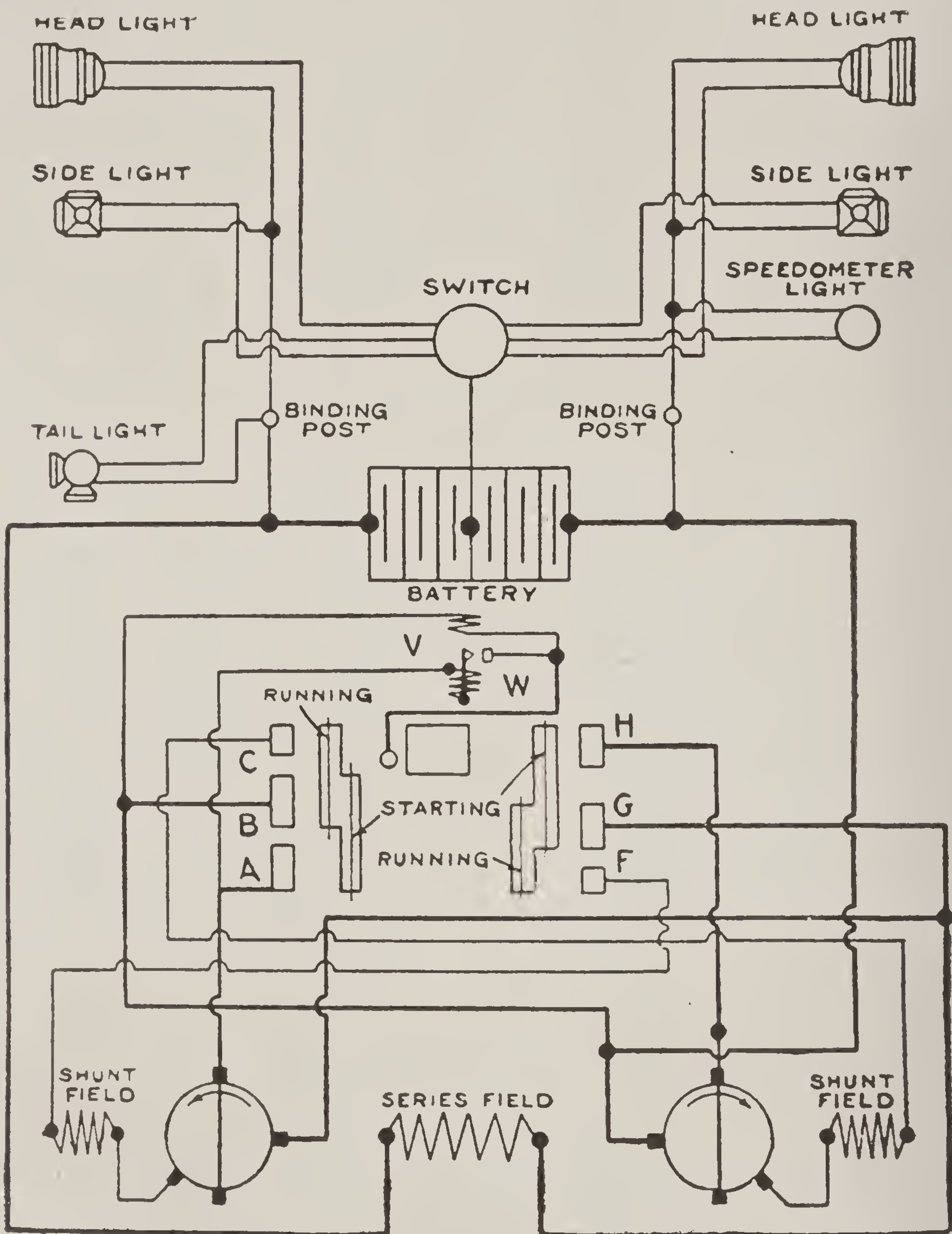


Fig. 343. Wiring Diagram for Wagner Twelve-Volt Single-Unit Two-Wire System (Early Model)

the fingers mentioned when the drum is revolved part way in either direction by the lever, shown at the right, which engages the shaft M.

Battery Cut-Out. This is of conventional design. For description and explanation of operation, see previous systems in which a battery cut-out, or automatic switch, is employed. Methods of locating trouble are given in connection with instructions farther along.

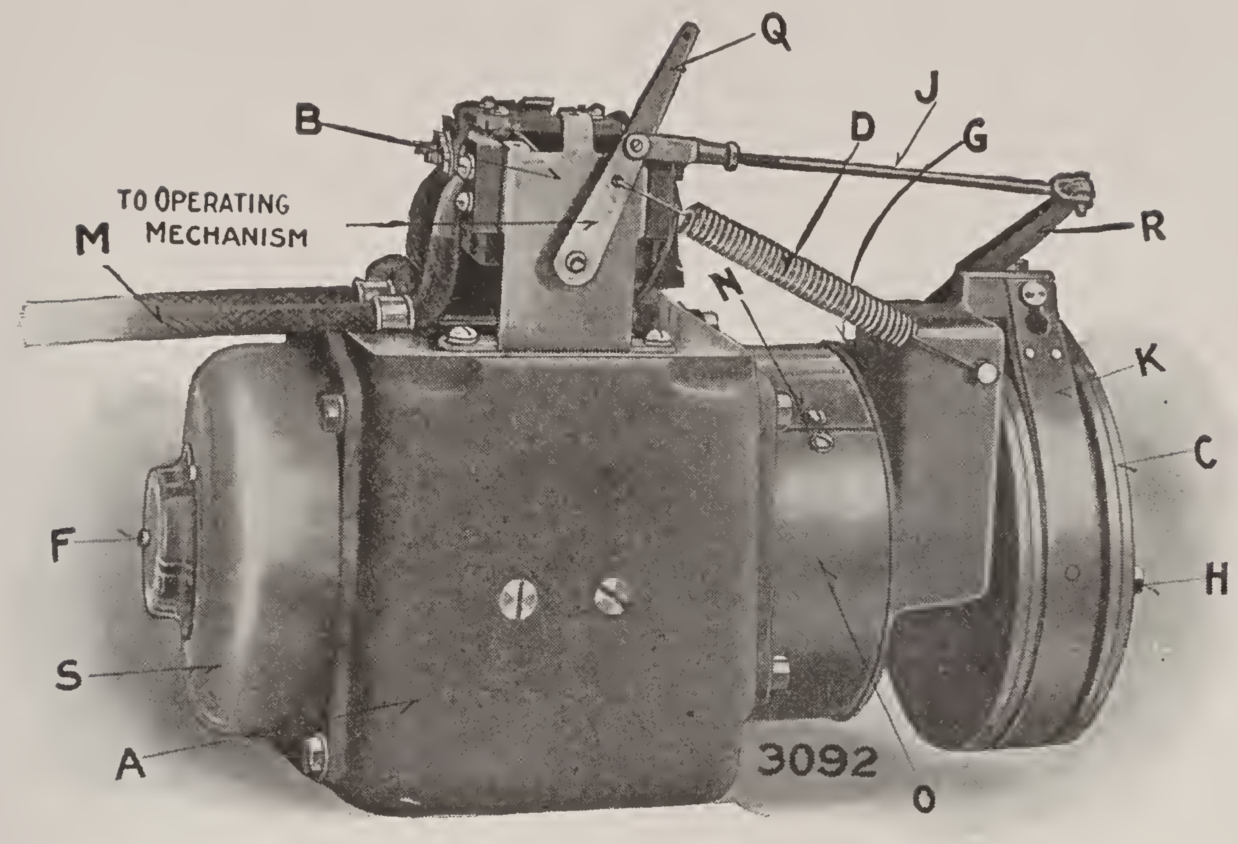


Fig. 344. Wagner Control Switch of Drum Type. A—Starter Frame; B—Switch Support; C—Outside End Plate Gear Box; D—Return Spring; F—Oil Hole Screw; G—Self-Closing Oiler; H—Oil Plug; J—Connecting Rod; K—Brake Band; M—Battery Leads; N—End Plate Screws; O—Back End Plate Shield; Q—Starting Switch Lever; R—Brake Band Lever; S—Front End Plate Shield

Courtesy of Wagner Electric Manufacturing Company, St. Louis, Missouri

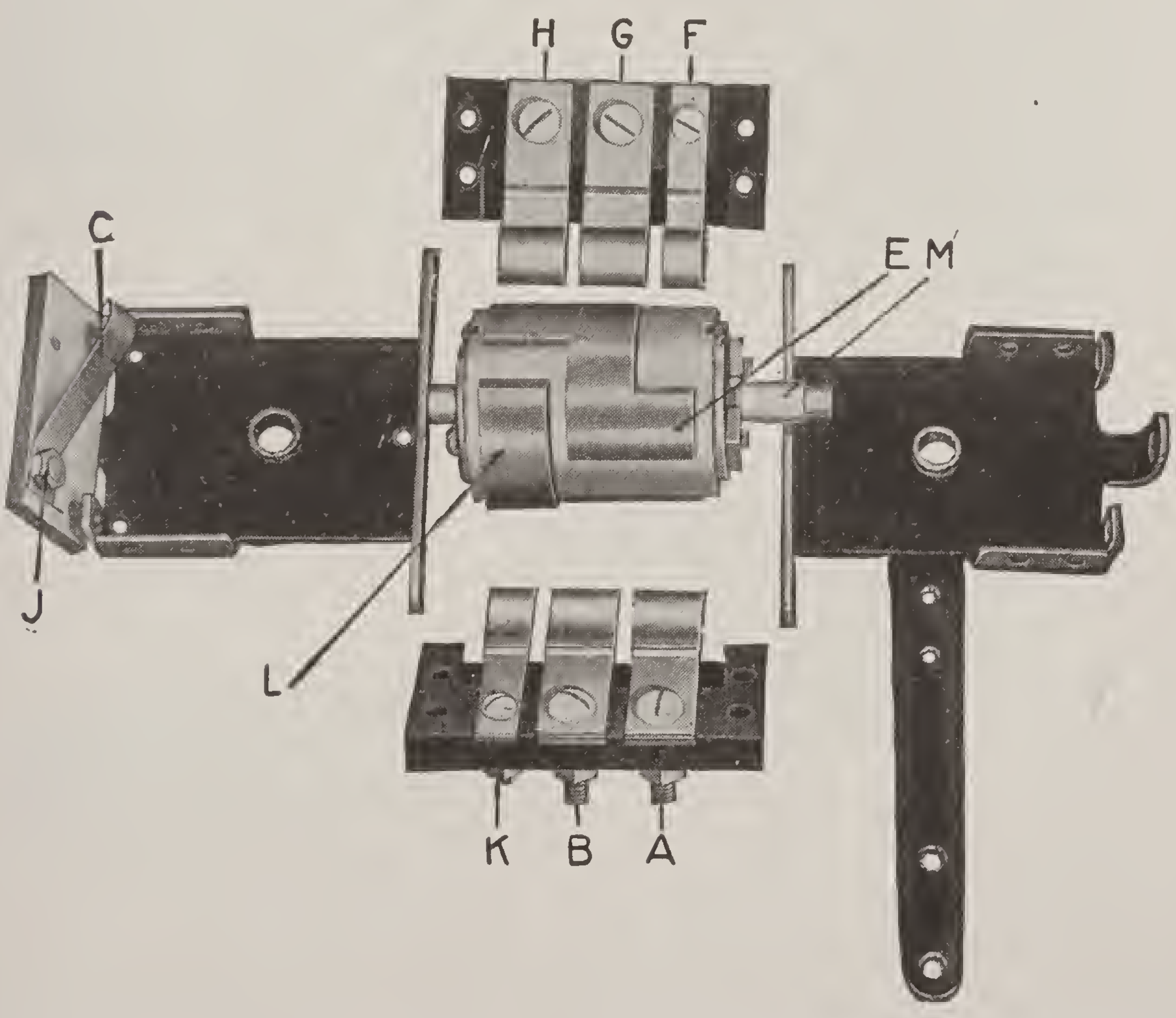


Fig. 345. Exploded View of Drum Switch. A, B, F, G, H, and K—Contact Screws to Contact; C—Auxiliary Contact Finger; E—Drum Contact; J—Screw Holding C; L—Auxiliary Drum Contact; M—Shaft

Planetary Gear. The external form of the different gear boxes used on the early-model single-unit Wagner starter is the same, but

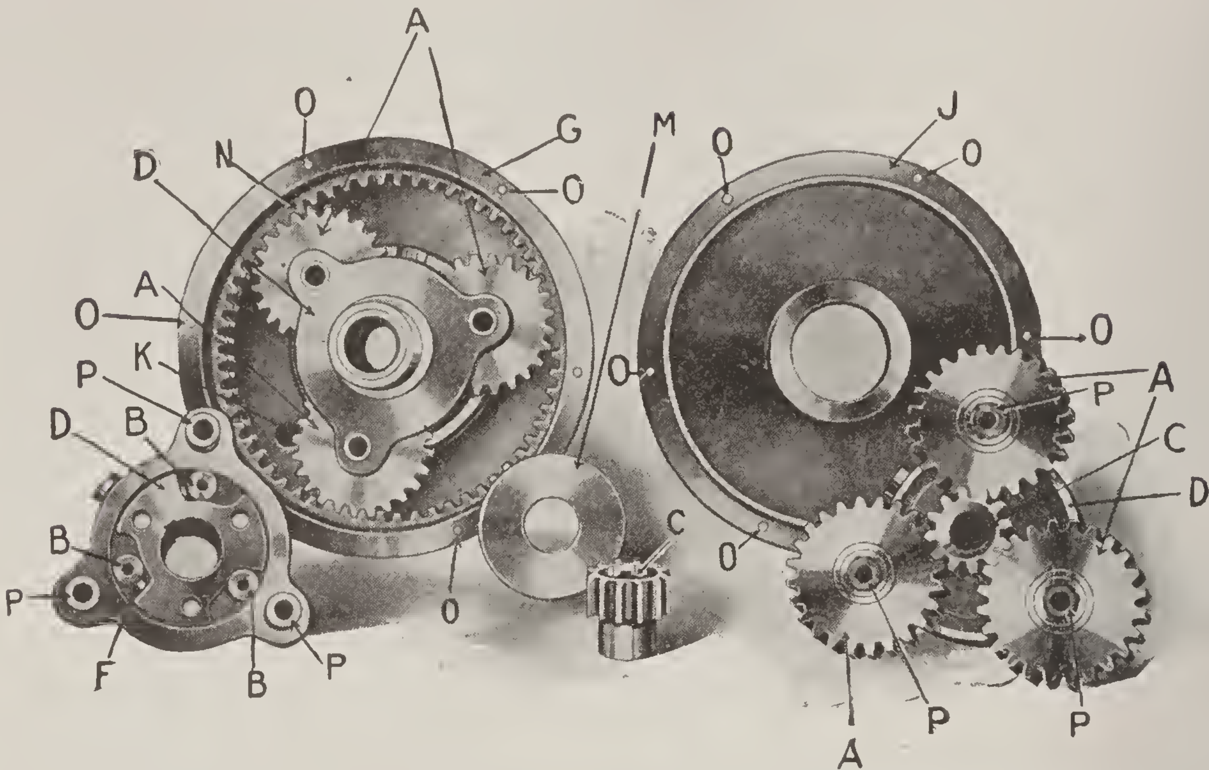


Fig. 346. Exploded View of Planetary Gear Transmission. A—Planetary Pinion; B—Rolling Pawl; C—Center Pinion; D—Planetary Hub; E—Pawl Seat; F—Pawl Plunger; G—Internal Gear; H—Inside End Plate; J—Outside End Plate; K—Oil Plug; M—Sheet-Steel Disc

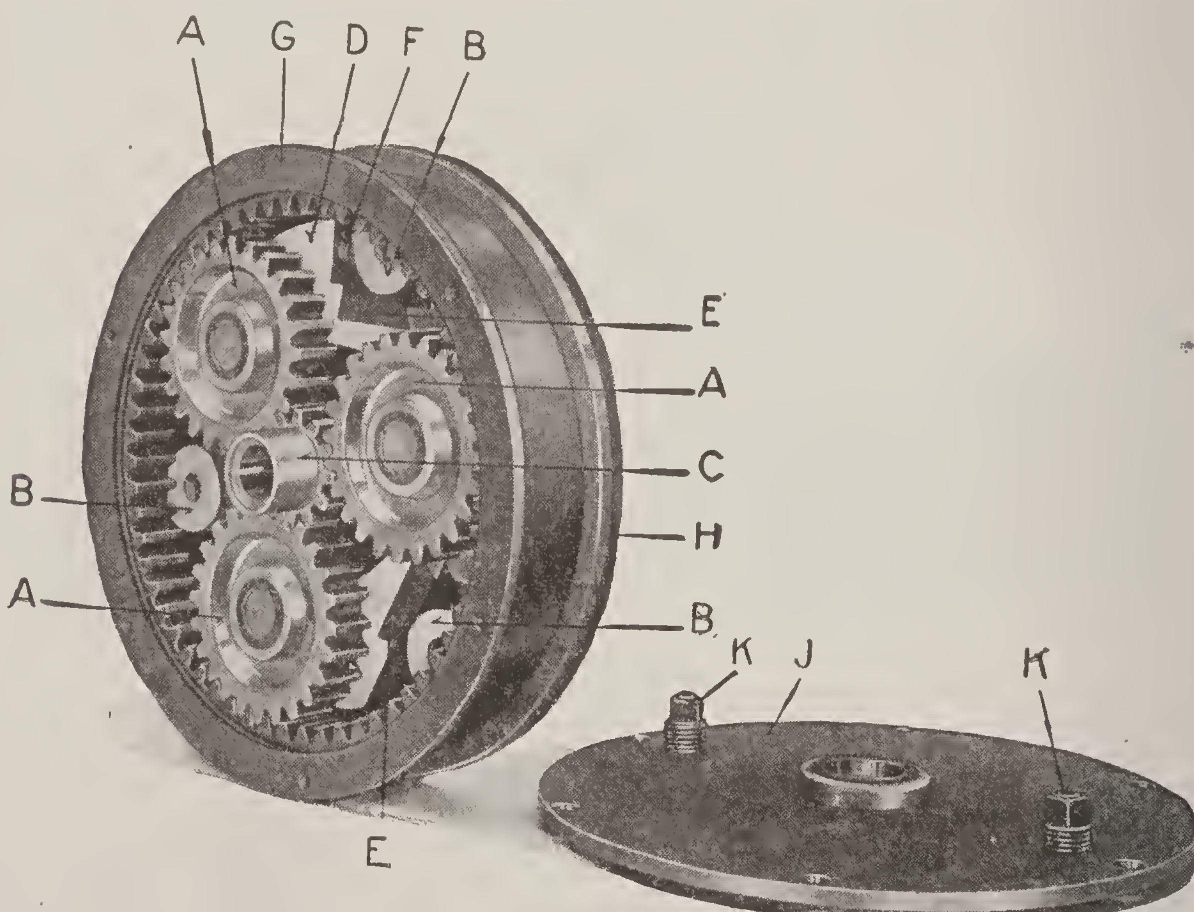


Fig. 347. Assembled Planetary Gear. Letters same as Fig. 346

their internal construction differs somewhat. The details of the two types employed are shown in Figs. 346 and 347. The principle employed is that of the planetary gear as used to obtain first,

or low, and high speeds on early-model light cars. The unit consists of a central, or sun, gear *C*, Fig. 347, and three planet pinions *A* meshing with the central gear and also with the internal gear ring *G*. For starting, the tightening of the brake band on the outer groove of the internal gear holds it fast, so that the drive is through the central gear and the reducing pinions in engagement with it and the gear ring, while, for running, the rollers *B* in the clutch *D* lock the gears together so that when generating the gear revolves idly as a unit.

Instructions. The instructions previously given in connection with other systems apply here. For failure to generate, lack of capacity, grounds, or short-circuits in windings, and for keeping the

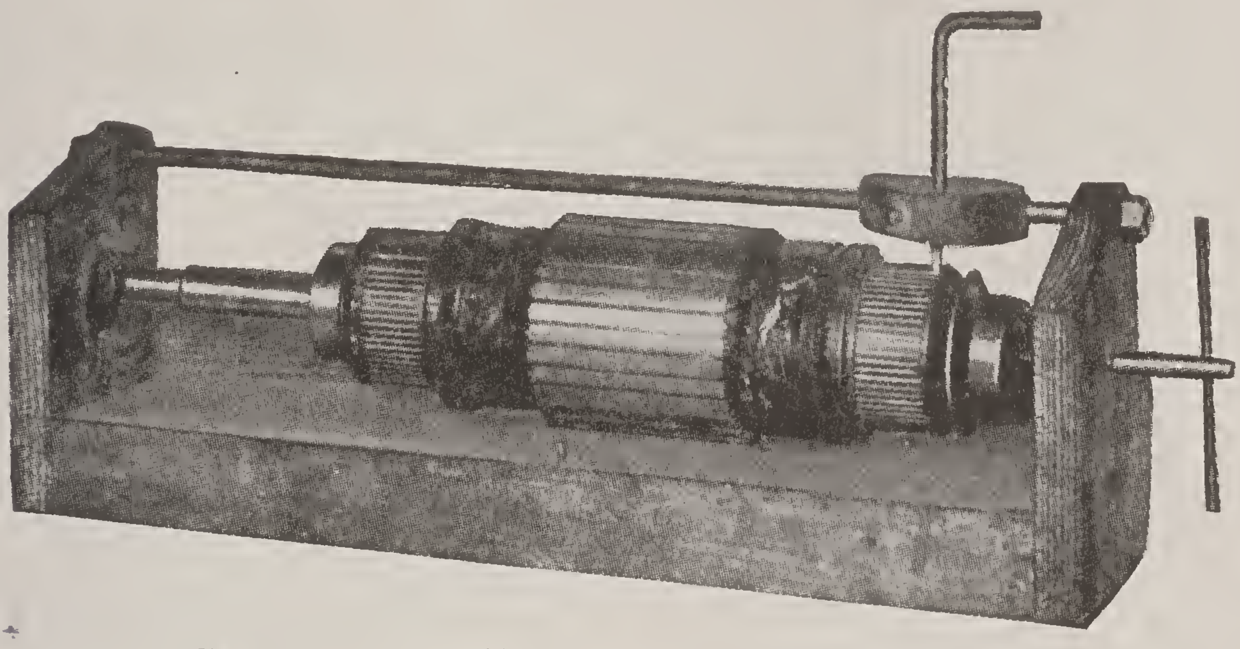


Fig. 348. Jig for Holding Armature and Tooling Commutator

commutator and brushes in condition, see instructions already given, as well as Summary of Instructions at the end of Part VIII.

Method of Tooling Commutator. A different method of undercutting the mica of the commutator is recommended from that already described in connection with the Delco system. This is illustrated in Fig. 348. The armature is removed from the generator and mounted in a simple jig, as shown. The jig is made of 1-inch oak, while ordinary machine screws held in place by lock nuts are utilized as the centers. The bar, or guide, on which the cutter operates, can be made of $\frac{1}{2}$-inch rolled-steel rod, while the cutter itself should be made of $\frac{1}{4}$-inch drill rod. The point of this cutter is ground sharp, like the parting tool used on a lathe or planer, to the thickness of the mica between the commutator bars. The cutter is moved backward and

forward on its guide in the same manner as a planer or shaper tool, and the armature is rotated one segment at a time to bring the mica sections under the tool successively. Where there is not sufficient work of this nature to make it worth while to build the jig, a simple hand tool may be used, Fig. 349. This can be made of a discarded hacksaw blade or a new one, about 8 inches long. One of the ends is ground similarly to the cutter described for the jig, while the other should be shaped like a hook, having the same kind of point as the cutter end. Around the center of this tool should be folded a piece of heavy tin (sheet iron) and the whole wrapped with electric tape. This will prevent the brittle saw blade from breaking and make it much easier to handle. The mica is removed by forcing the sharp end of the tool from the outer edge of the commutator surface to the inner edge, and the rough cut thus made is finished by drawing the hooked end of the tool back through the groove in the opposite direction. To do the job properly, the armature should be held in a vise, otherwise it is liable to move, or the tool is liable to slip, and the copper be cut away with very poor results. Fig. 350 shows the commutator before and after undercutting the mica.

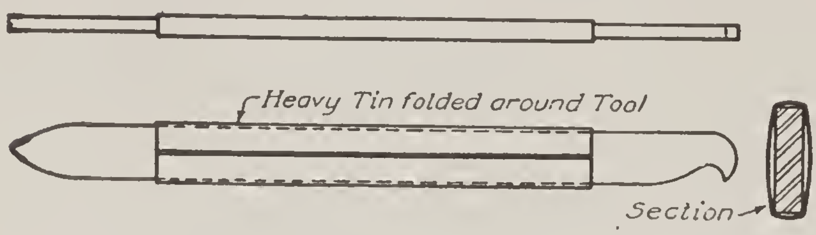


Fig. 349. Diagram of Simple Hand Device for Tooling Commutator

A needle-pointed tool should never be used, as it will simply, make a V-shaped cut in the mica, removing too much in depth and not enough in width. The mica must be cut out clean and square, and a small magnifying glass should be used to see that all of the pieces adjacent to the bars have been removed. After removing the mica, the armature should be placed in a lathe, and a light cut taken from the commutators, i.e., just enough to remove all roughness

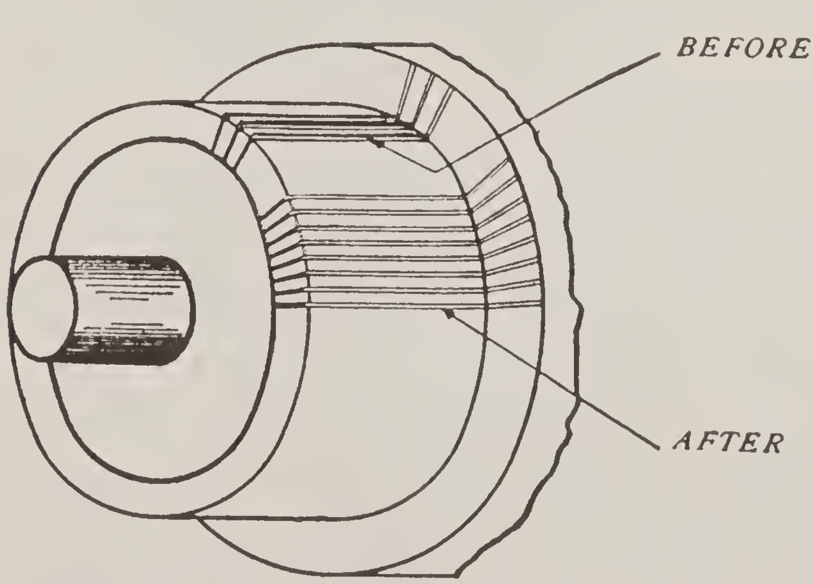


Fig. 350. Diagram Showing Commutator Sections before and after Tooling

and flat spots. The cutting tool employed should be very sharp, so that the soft copper will not be dragged from one segment to another. After turning, fine sandpaper should be used to smooth the commutator. Whether the brushes are replaced with new ones or the old ones are retained, they must be sanded-in to the commutator (see Delco instructions). The springs also should be tested for tension; they must never be allowed to become loose enough to permit the brushes to chatter when the generator is running, as this would interfere seriously with its output.

Lack of Capacity through Faulty Gear Box. Should the battery not charge properly, note whether in starting the lights brighten

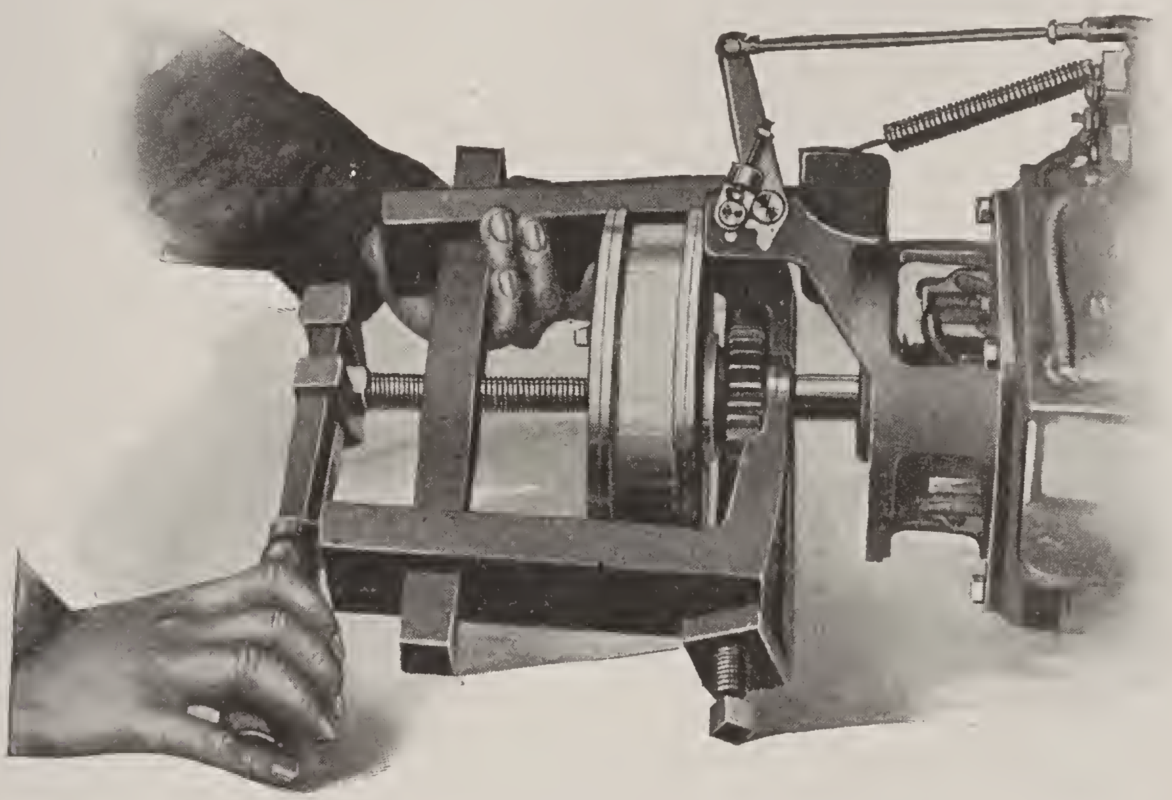


Fig. 351. Method of Pulling Wagner Gear Box with a "Come Along"
Courtesy of Wagner Electric Manufacturing Company, St. Louis, Missouri

perceptibly with the car running below 5 miles per hour, while at high speed they remain dim. This indicates that the brake band of the gear box does not release, owing either to improper adjustment of the tightening screw or to something getting between the band and drum. To remedy, the band adjusting screw should be turned until the band feels free when the starting lever is in the running position. If something has caught between the band and the drum, its removal usually will be the only remedy necessary.

Should the battery show signs of exhaustion, and if there is no noticeable increase in the brightness of the lamps when the car reaches a speed of 10 miles per hour or its equivalent, the trouble

probably is in the gear box. Remove the front end plate and note if the commutator is rotating. If not, and the reason therefor is not apparent on an inspection of the gears, it may be necessary to remove the gear box. A "come along", such as is employed for taking off Ford wheels, is necessary for this, Fig. 351. It may be found that some of the parts need replacement, or that an entirely new gear box is necessary.

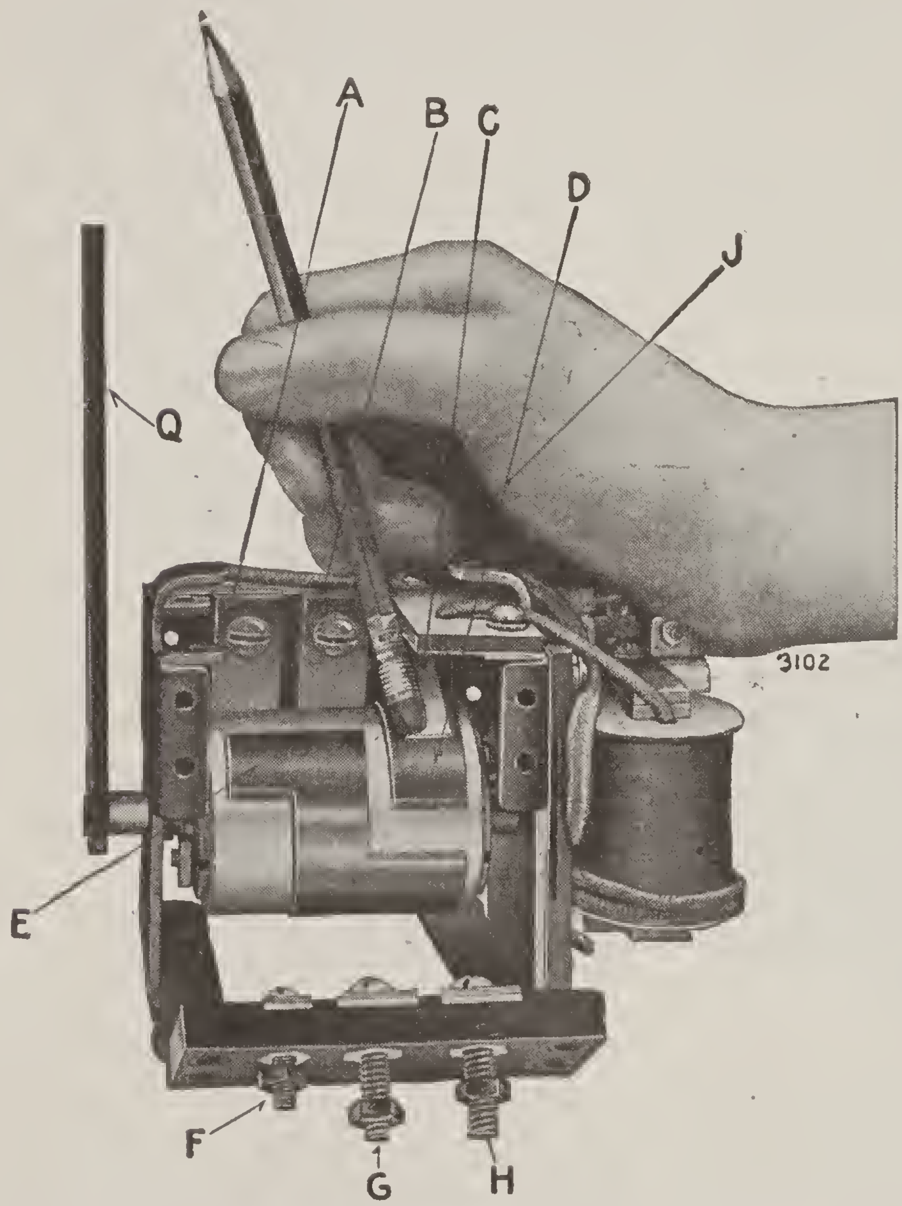


Fig. 352. Details of Wagner Starting Switch. A and B—Large Contact Finger; C—Auxiliary Contact Finger; D—Auxiliary Contact; E—Drum Switch; F, G, and H—Drum Switch Studs; J—Screw Leading to C; Q—Starting Switch Lever

Failure Due to Battery Cut-Out. If the failure to charge the battery be not due to the gear box, remove the cover of the cut-out and see if it is operating properly. When the engine is running at a speed equivalent to 15 miles per hour, the contact should spring away from the adjusting screw. If it does not, connect a voltmeter across the terminals *B* and *H* of the switch, Fig. 352. Should the voltmeter needle not move, examine the contact fingers connected to the studs *C* and *F* and see that they make firm contact with the drum of the switch. Place the end of a pencil on the contact finger *D* and bear down lightly; if the main contact maker then springs away from the adjusting screw, the cause of the trouble is an open circuit at this contact. Bend *D* so that it bears down on the drum segments; should the contacts not close on making this test, the trouble will be an open connection, either in the generator itself or between the generator and the cut-out (switch).

Should the voltmeter give a reading of 6 volts while the contacts do not close, it shows that the shunt coil of the cut-out is open and indicates that its connections are broken or that the trouble is in the coil itself. This may be confirmed by operating the contacts by hand—pushing the contact away from the adjusting screw until it touches the stationary contact. If it remains in that position, the generator is charging the battery, but the shunt coil of the cut-out is out of action and the cut-out will function automatically as it should.

If, under the conditions mentioned in the first paragraph under this heading, the cut-out closes, connect the voltmeter as described and accelerate the engine to a speed corresponding to 25 miles per hour. If the reading is then 15 to 20 volts, the trouble may be looked for in a break in the generator connection to the cut-out. Should it not be possible to locate any break, it may be in the series coil of the cut-out, in which case a new cut-out will be necessary.

Switch or Generator Parts to Be Adjusted. If the starting lever of the switch is not returning to the proper position for running after starting the engine, it will be indicated by a low battery and dim lights. Adjust so that the lever will go to correct position for running and see that the contact fingers of the switch are making proper contact with the drum.

In case the battery does not get sufficient charge, connect an ammeter to the terminal *D* of the switch and to *W* of the cut-out. At a speed equivalent to 15 miles per hour, the ammeter should read 7 to 9 amperes if the generator is working properly. If it does not, examine the commutator, brushes, and wiring, as previously described.

Six-Volt; Two-Unit

General Characteristics. This type is similar in characteristics to most of the other makes of this class already described.

Generator. The generator is the multipolar (four-pole) shunt-wound type.

Regulation. The regulation is of the inherent or bucking-coil type, integral with the field windings of the generator.

Starting Motor. The motor is four-pole and series-wound, driving through a reducing gear mounted on the motor housing, Fig. 353.

Control. *Battery Cut-Out.* The complete instrument, minus its cover, is shown in Fig. 354. It is of standard design and is intended

to be mounted in the tool box under the driver's seat. As shown in the photograph, the upper binding post is the series-coil connection, the central binding post just below it is the shunt-coil connection,

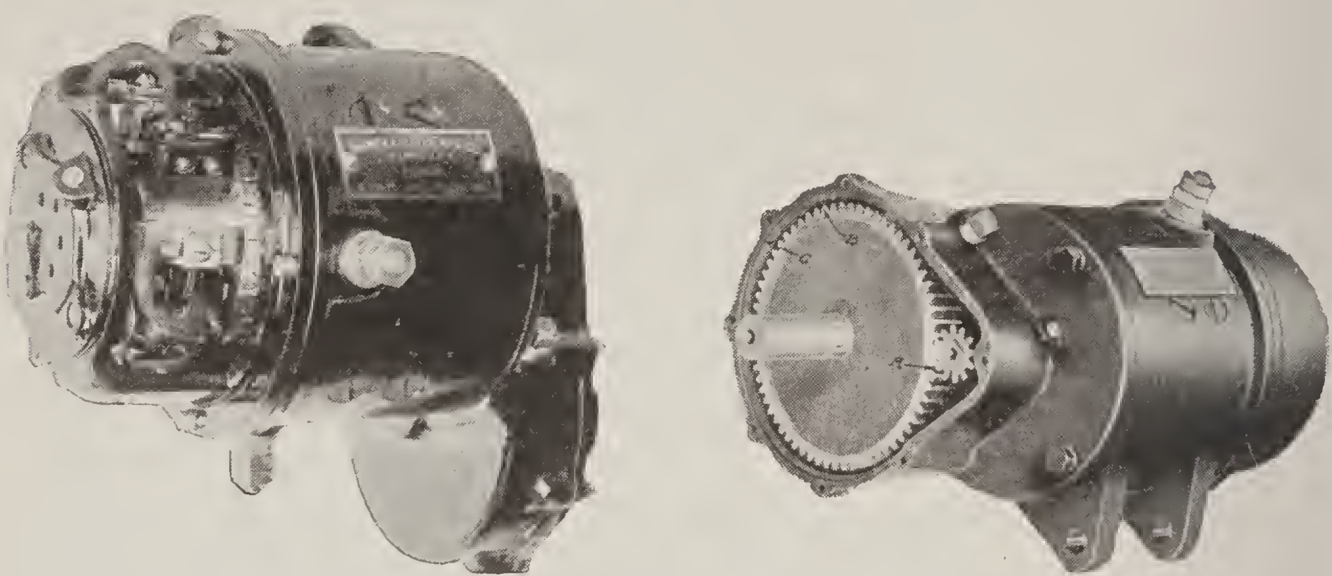


Fig. 353. Wagner Six-Volt Two-Unit Type Starting Motor. Left—Commutator End; Right—Gear End
Courtesy of Wagner Electric Manufacturing Company, St. Louis, Missouri

while the lowest binding post is a connection completing the circuit through both coils to the battery.

Switch. The switch is of the circular knife-blade type, two sets of spring contacts close together being pressed down over the stationary contact against the spring, as shown in Fig. 355 which illustrates the parts of the switch.

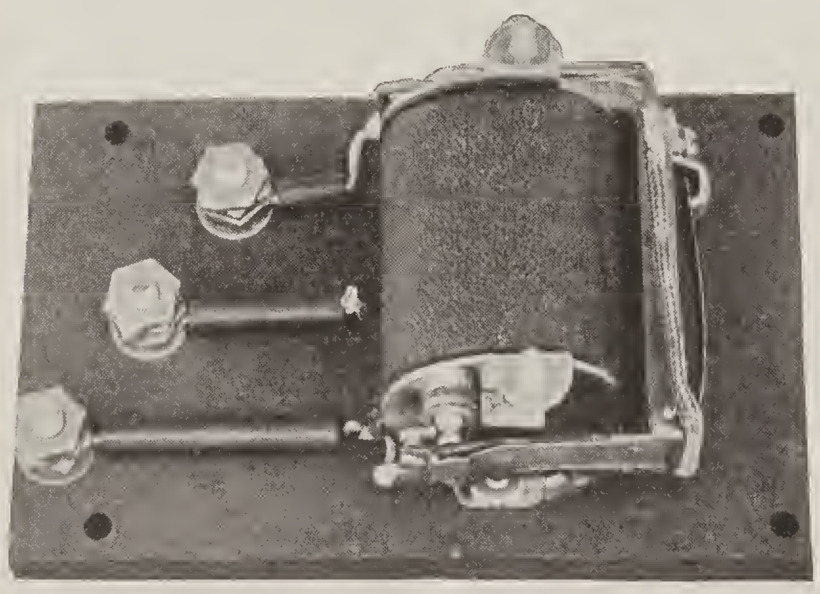


Fig. 354. Wagner Cut-Out

Wiring Diagram. A typical wiring diagram of the Wagner two-unit system as installed on the Scripps-Booth four- and eight-cylinder models is shown in Fig. 356. The only difference in the wiring of the two models has to do with the ignition and merely affects the distributor connections, as illustrated by the panel in the upper right-hand corner, which shows the distributor and connections for the four-cylinder car. As the system is a single-wire type, one side of every circuit is grounded, the spark plugs themselves representing the grounded side of the high-tension ignition

circuit. The caution on the diagram—*Never run generator with battery removed from car nor with wire disconnected from generator*—applies not only to the Westinghouse system but to practically every other system as well.

Instructions. *Ground in Starting or in Lighting Circuits.* When the blowing of a fuse on one of the lighting circuits is due to a ground, or a similar fault is suspected in the starting system, it may be tested for either with the lamp outfit already described or with the low-reading voltmeter, as follows:

Disconnect one battery terminal, taping the bare end to prevent contact with any metal parts of the car, and connect one side of the voltmeter to this terminal. Attach a length of wire having a bared end to the other terminal of the voltmeter, as shown in Fig. 357.

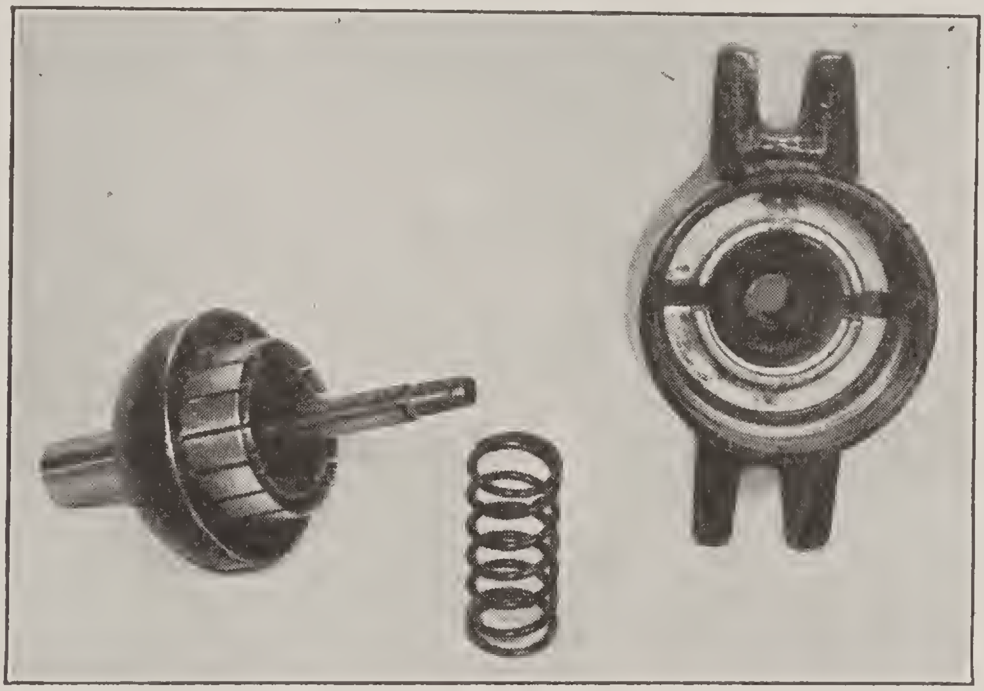


Fig. 355. Details of Wagner Switch
Courtesy of Wagner Electric Manufacturing Company, St. Louis, Missouri

Connect the bared end of the free wire to some part of the car frame; making certain that good electrical contact is made. Disconnect the generator and starting motor completely, open all lighting switches, and be sure that ignition switch is off. If there is no ground in the circuit, the voltmeter will give no indication. Be sure that none of the disconnected terminals is touching the engine or frame; to insure this, tape them.

Should the voltmeter give a reading of 4 volts or more, it indicates that there is a ground in the wiring between the battery and the junction box, or in the wiring between the junction box and the generator or the starting motor. If the voltmeter reads less than 4

volts but more than $\frac{1}{2}$ volt, all wiring and connections should be carefully inspected for faults. This test should be repeated by reversing the connections, that is, by reconnecting the wires on the side of the battery circuit that has been opened and disconnecting the other side.

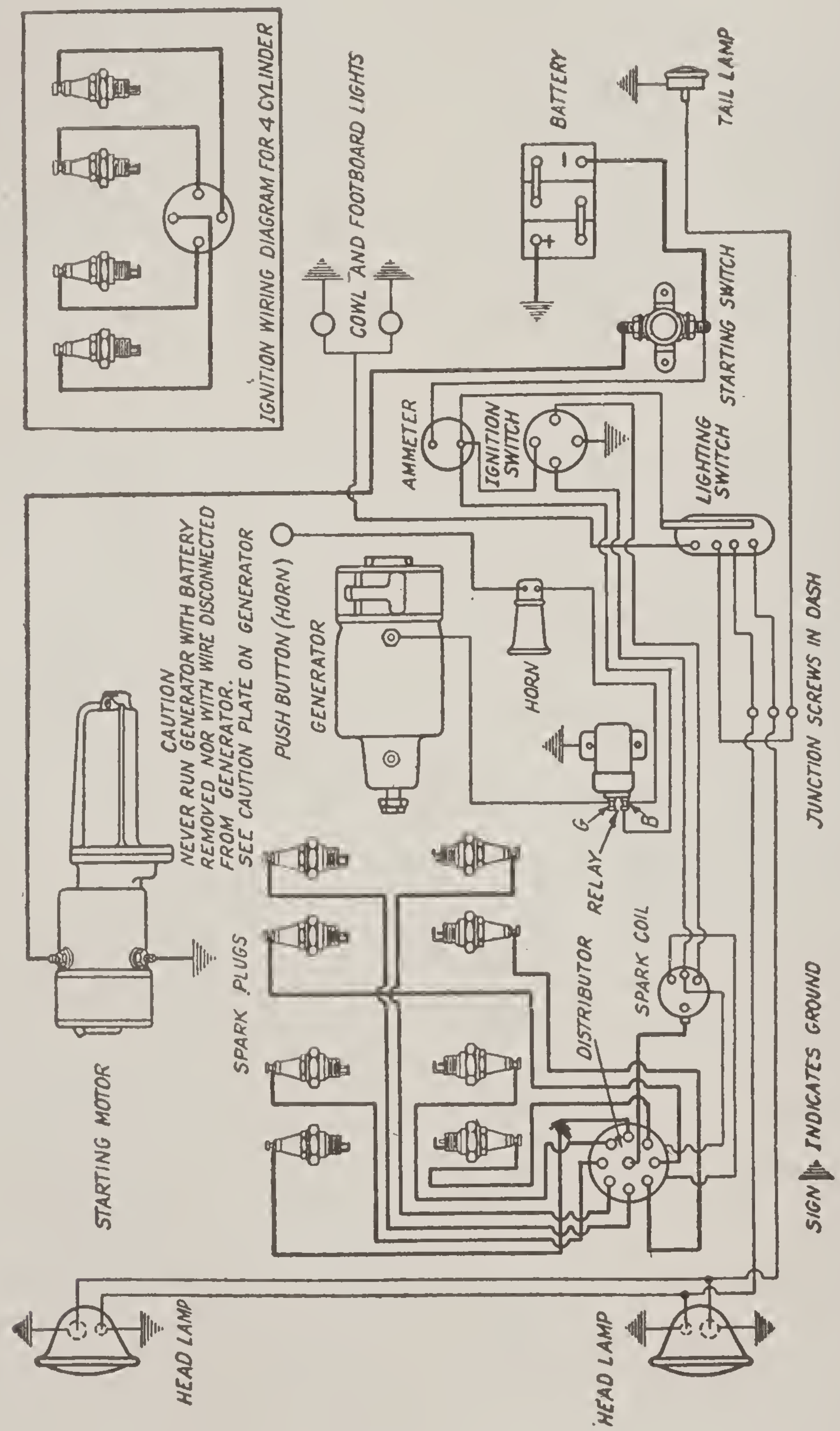


Fig. 356. Wagner Two-Unit System for Scripps-Booth Four- and Eight-Cylinder Models

Localizing Any Ground. To localize any fault that the reading of the voltmeter may show, reconnect the wires to the starting motor and close the starting switch; any reading of the voltmeter with such connections will indicate that the ground is in this circuit. Should no ground be indicated with these connections, disconnect

the starter again and reconnect the generator; if the voltmeter records any voltage, the ground is in the generator circuit. With both starter and generator disconnected, the voltmeter being connected first to one side of the battery and then to the other, operate the lighting switches, the ignition switch, and the horn, one at a time, and note whether the voltmeter needle moves upon closing any of these switches. A voltage reading upon closing any of these switches will indicate a ground in that particular circuit.

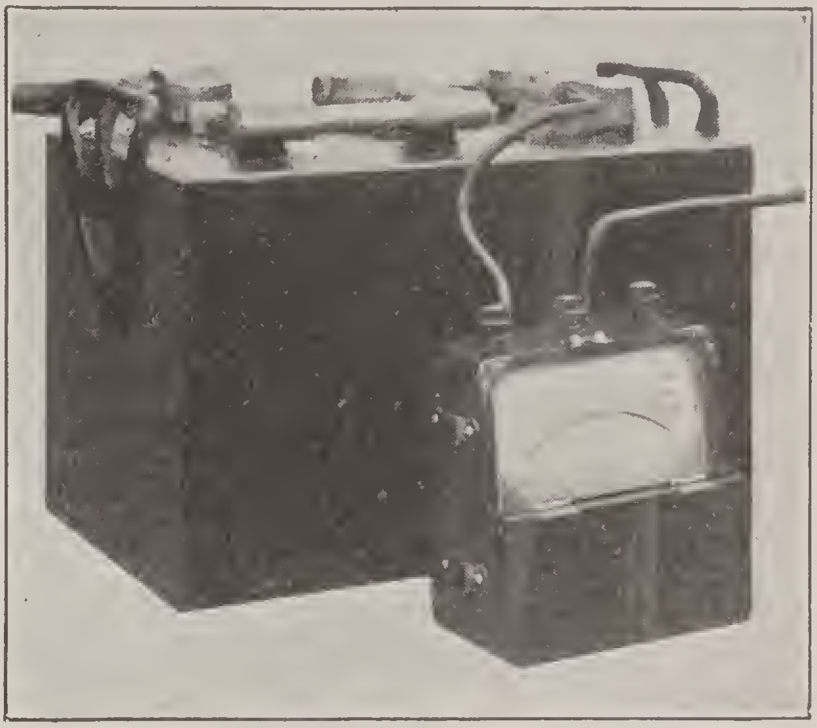


Fig. 357. Testing for Grounds with Voltmeter in Two-Wire System

Short-Circuit Tests. To test for short-circuits, substitute the ammeter for the voltmeter, but do not connect the instrument to the battery. The shunt reading to 20

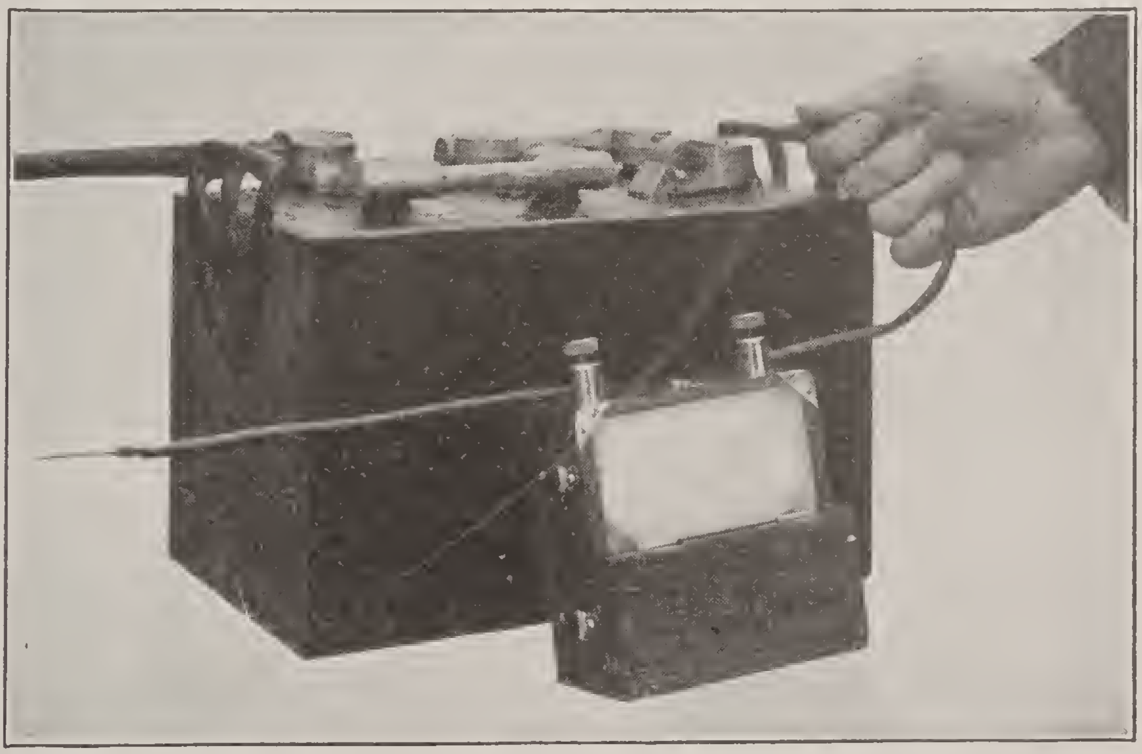


Fig. 358. Testing for Short-Circuits with Ammeter in Two-Wire System

amperes should be employed, one side of the ammeter being grounded on the frame as previously described, and the other being connected with a short wire that can be touched to the open side of the bat-

tery, Fig. 358. Disconnect the starter and the generator and open all the switches, then touch the bare end of the wire to the battery terminal on the open side as shown. Any reading, no matter how small, will indicate a short-circuit (two-wire system) in the wiring between the battery and junction box or between the latter and the starter, or generator. If the ammeter reading shows a heavy current, there is a severe short-circuit.

Localizing a Short-Circuit. The short-circuit may be localized in the same manner as described for the voltmeter test, i.e., connect the starter and test; disconnect the starter, connect the generator and test. A reading on the generator test may be due to the contacts of the cut-out sticking together. If the cut-out contacts are open and the ammeter registers, there is a short-circuit in the generator windings.

Disconnect the generator again, remove all the lamps from the sockets, and turn on the lighting-circuit switches one at a time, touching the wire to the battery terminal after closing each switch. A reading with any particular switch on indicates a short-circuit in the wiring of the lamps controlled by that switch. Only one switch should be closed at a time, all others then being open. This test should be made also with the ignition switch on but with the engine idle. The ammeter then should register the ignition current, which should not exceed 4 to 5 amperes. If greater than this, the ignition circuit should be examined.

Cautions. Do not attempt to test the starter circuit with the ammeter as it will damage the instrument. To test the starter circuit, reconnect as for operating, removing the ammeter. Close the starting switch; a short-circuit in the wiring will result either in failure to operate or in slow turning over of the engine. See that the switch parts are clean and that they make good contact. If the short-circuit is in the winding of the starting motor, there will be an odor of burning insulation or smoke.

The battery must be fully charged for making any of these tests. While the effect either of a ground or of a short-circuit will be substantially the same, its location and the remedy will be more easily determined by ascertaining whether it is the one or the other. Instructions for making these tests have already been discussed in the Gray & Davis section.

WESTINGHOUSE SYSTEM

Twelve-Volt; Single-Unit; Single-Wire

Dynamotor. The single unit of the 12-volt system, or the "motor-and-generator" as the manufacturers term it, is a bipolar machine, both the generator and starting-motor windings of which are connected to the same commutator. Installation is usually by means of a silent chain, as on the Hupp (1915 and earlier). The characteristics of this type of machine are such that when running at a speed equivalent to 9 miles per hour or less, it acts as a motor, and when the speed increases, it automatically becomes a generator and begins to charge the battery.

Regulation. The third-brush method of regulation is employed, the amount of current supplied to the shunt fields by this brush

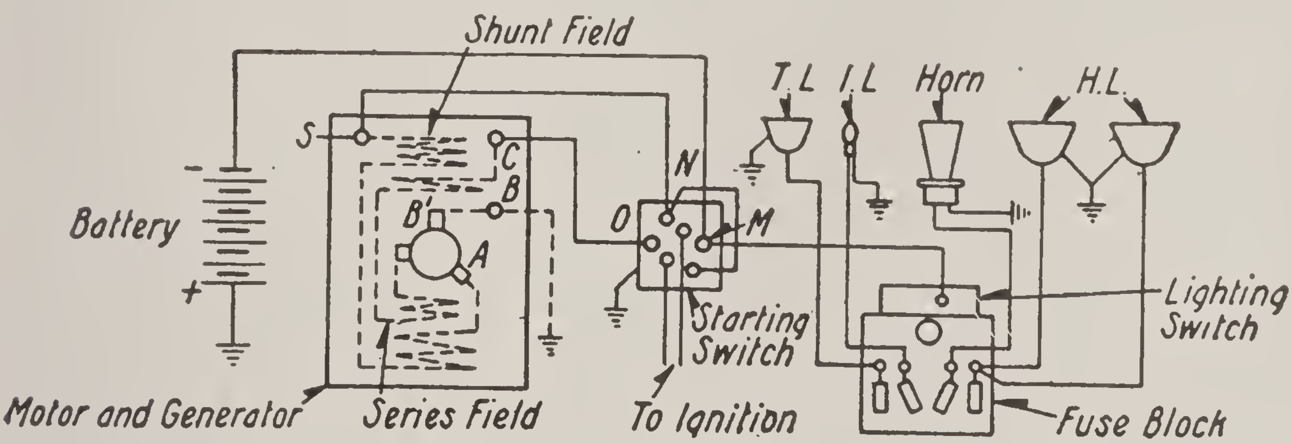


Fig. 359. Wiring Diagram for Westinghouse Single-Unit System on Hupmobile

decreasing as the magnetic field of the generator becomes distorted owing to increased speed.

Control. The switch employed with this type of combined unit is the regular single-throw single-pole switch used on lighting-plant switchboards. This switch controls both the ignition and the starting-motor circuits and, at starting, is thrown on and left closed as long as the car is running.

Wiring Diagram. The connections of the Hupp installation are shown in Fig. 359.

Instructions. *Battery Charging.* As the unit acts as a motor to drive the engine when the latter is running at a speed of less than the equivalent of 9 miles per hour on high gear, slow driving or permitting the engine to idle at a very low speed when the car is standing will discharge the battery. Where no fault in the wiring or connections exists and the battery will not stay charged (the

generator, of course, working properly), this practice may be the cause of the trouble. If the voltage drops to 10 or 11 volts, with the headlights on but with the engine stopped, it indicates that the battery is practically discharged. This voltage reading will be somewhat higher in summer than in winter. The remedy is to run with fewer lights at night or to run the engine for longer periods in the daytime, or at higher speeds. Running solely at night will not keep the battery sufficiently charged, as most of the generator output is consumed by the lamps. Should the battery become discharged to a point where it cannot operate the starting motor, disconnect the wires C and S at the dynamotor, taping their terminals to prevent contact with any part of the engine or chassis. Start the engine by hand and, when running at a speed of about 500 r.p.m., reconnect these wires, *being sure to connect wire S first*, when the battery will begin to charge.

Fire Prevention. Gasoline or kerosene is frequently employed to wash automobile engines. Before doing so, be sure that the starting switch is open, and disconnect the negative terminal of the battery, taking care that it does not come in contact with any metal parts of the car. To make certain of this, it is better to tape the metal terminal. Allow the gasoline to evaporate entirely before reconnecting the battery, as a flash or spark would be liable to ignite the vapor. This naturally applies to all cars, although only such as are equipped with the Westinghouse single-unit or the Dyneto single-unit have starting switches which remain closed all the time the engine is running.

Weak Current. If the dynamotor fails to operate when the starting switch is closed, open the switch and test with the portable voltmeter. If it indicates less than 11 volts, the battery is run down; if it indicates 12 volts or over, look for a loose connection or an open circuit (broken wire) either in the connection from the battery to the starting switch, from the switch to the dynamotor, from the latter to the ground, or from the battery to the ground, in the order named. Dim burning of the lamps when the engine is stopped also indicates a discharged battery. When this is the case, it is advisable to recharge at once from an outside source, if possible.

A quick method of determining whether there is a ground in the wiring is to disconnect the battery wire and, the engine being stopped

and all lights turned off, touch the disconnected wire to the terminal lightly. A spark, when this contact is made, will indicate a ground between the battery and the dynamotor or the switch. The testing lamp should then be used to locate the circuit in which the ground exists.

Failure to charge properly may be due also to imperfect contact at the brushes or to a break in the shunt-field circuit of the generator, as explained in previous instructions. If the shunt-field circuit is found open, the trouble doubtless has been caused either by a ground between the battery and the generator or by running the generator when it was disconnected.

To remove the brushes, lift the spring that holds the brush in the guide and take out the screw holding the brush shunt, when the brush

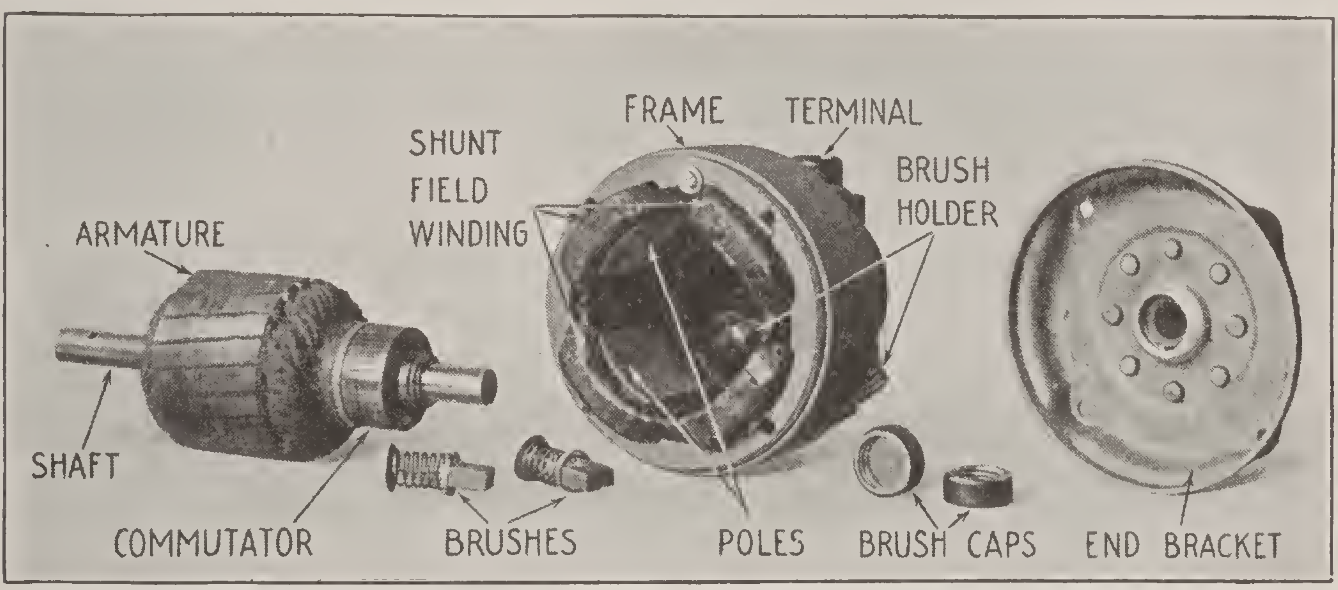


Fig. 360. Westinghouse Bipolar Generator for Six-Volt Double-Unit Single-Wire System
Courtesy of Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania

can be slipped out. Care should be taken to replace brushes in the same position, and if they do not bear evenly over their entire surface on the commutator, they should be sanded-in as described in the Delco instructions. The latter suggestion also applies to new brushes.

Six-Volt; Double-Unit; Single-Wire

Generators. Four types of generators are made, as illustrated in Fig. 116, Part III; in Fig. 157, Part IV; and in Fig. 360, shown herewith, the fourth being similar to the unit shown on this page except for the method of regulation employed, which is of the third-brush type.

Regulation. The reverse series-field winding, or bucking-coil, method is used in the first two types of generator, while a voltage regulator combined with the battery cut-out is employed on the

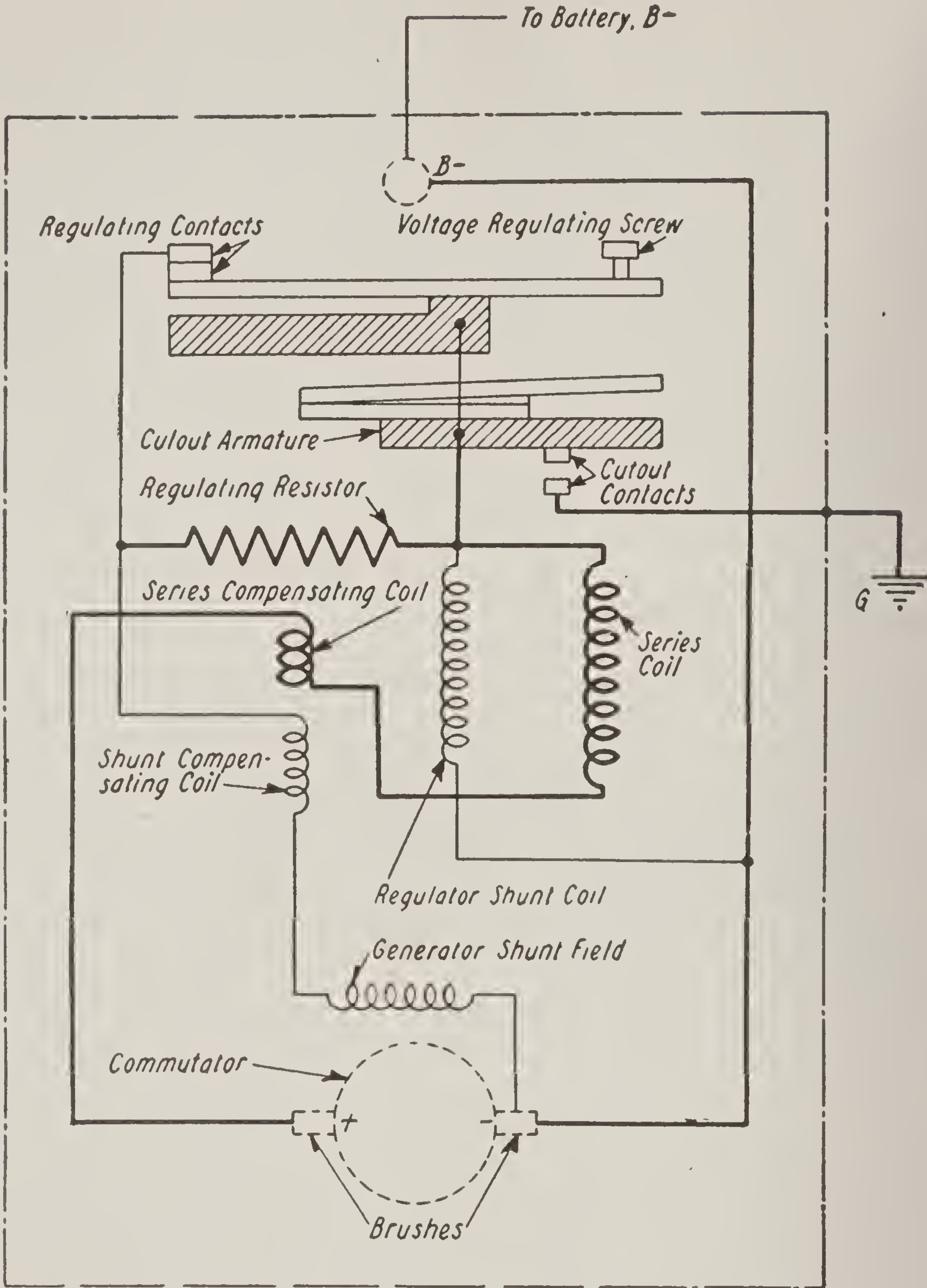


Fig. 361. Wiring Diagram for Westinghouse Generator with Self-Contained Regulator

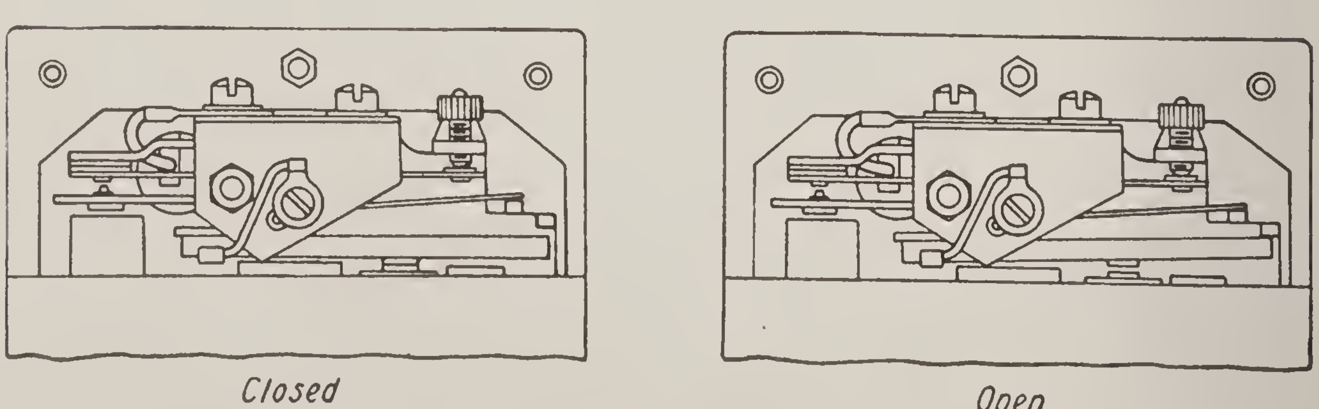


Fig. 362. Closed and Open Position of Westinghouse Cut-Out Switch

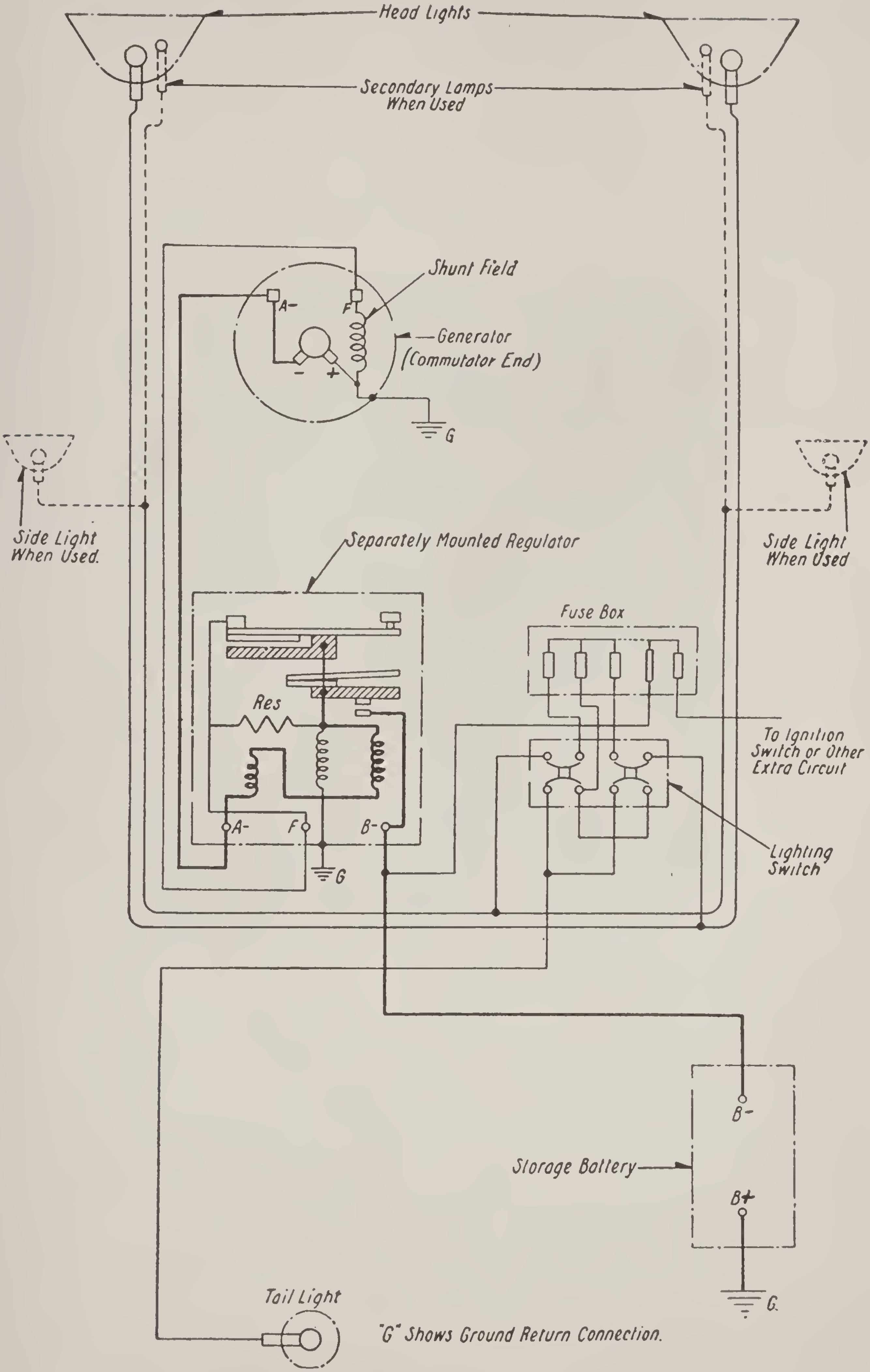


Fig. 363. Wiring Diagram for Westinghouse System with External Regulator

third, and the third-brush method on the fourth. This regulator is either self-contained, i.e., built in the generator, or is mounted independently. The connections of the built-in regulator are shown in Fig. 361. The open and closed positions of the contacts of the external cut-out are shown in Fig. 362.

Wiring Diagram. Fig. 363 shows the connections of the separately mounted regulator together with the charging and lighting circuits.

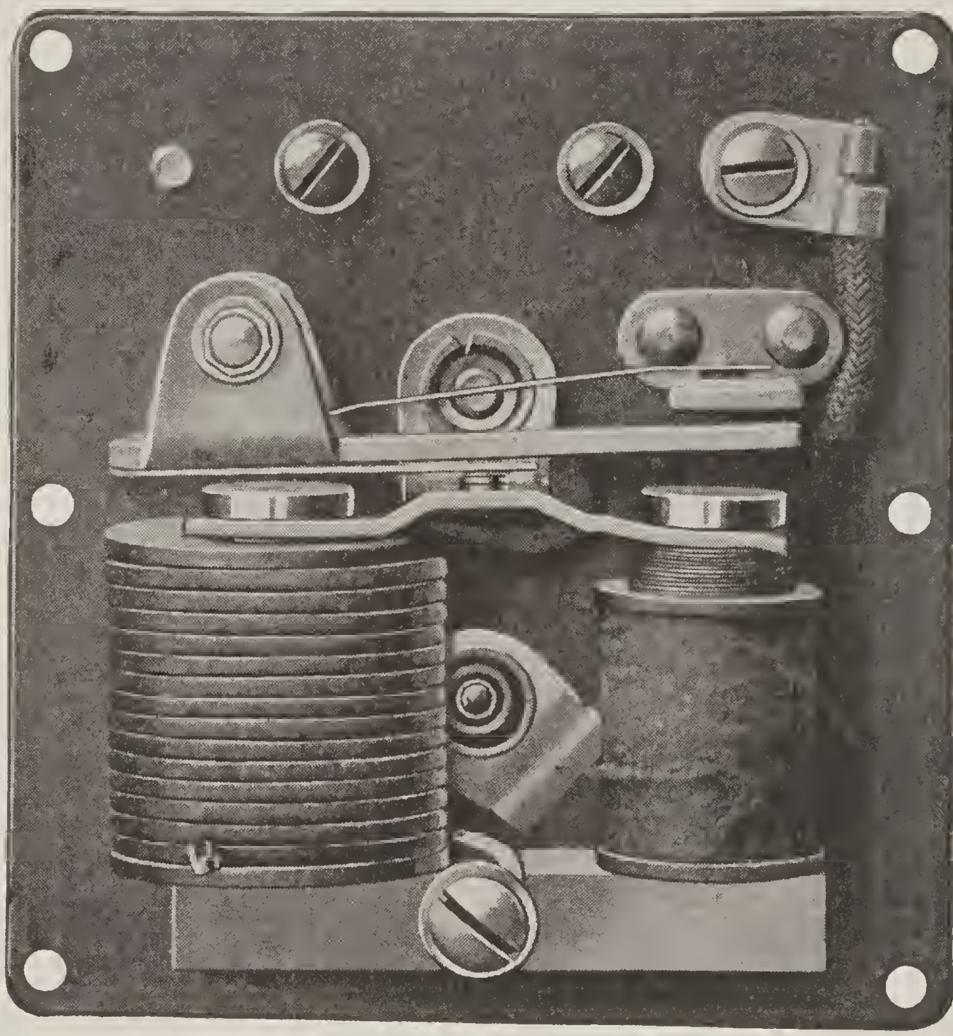


Fig. 364. Westinghouse Cut-Out Switch of Generator with Third-Brush Regulation

Battery Cut-Out. The type of automatic cut-out used with the type of generator employing the third-brush method of regulation is illustrated in Fig. 364. This may or may not be combined with a starting switch mounted on the engine side of the dash or some similar location. Fig. 365 is a wiring diagram showing the connections of the separately mounted cut-out with the third-brush generator. The cutting-in speed varies from five to ten miles per hour on high gear, varying with the gear ratio and wheel diameter of the car. This speed may be determined by running the car slowly and speeding up very gradually, meanwhile observing the increase in speed on the speedometer. The point at which the contacts close

will be indicated by a slight quick movement of the ammeter needle. The cutting-out speed is slightly below this to prevent constant

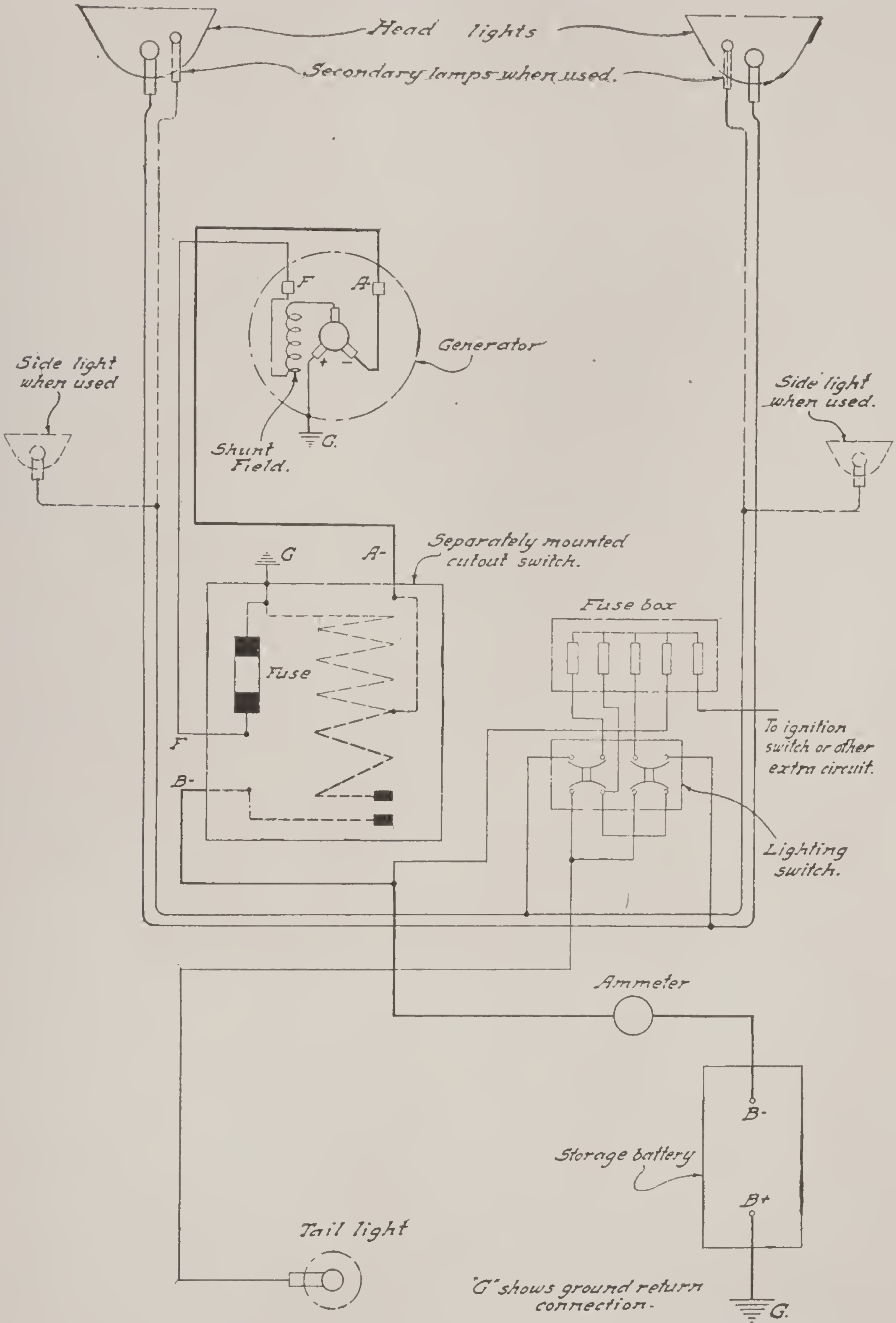


Fig. 365. Diagram of Connections for Complete Westinghouse System with Separately Mounted Regulator

vibration of the cut-out armature when the car is being driven close to the cutting-in speed.

Starting Motors. *Variations.* Several types are built to meet varying requirements; i.e., with self-contained reduction gearing, with single-reduction automatic screw pinion shift (Bendix drive), and with automatic electromagnetic pinion shift. The first two will be familiar from the descriptions already given of other makes. The third is similar in principle to the Bosch-Rushmore, but an independent magnet is employed instead of utilizing the armature of the motor itself for this purpose.

Magnetic Engaging Type. This type, as well as the other types of starting motors mentioned, may be operated either by a foot controlled switch or by a magnetically controlled switch put in action by a push button. The wiring diagrams, Fig. 366, show the circuits of both installations and also make clear the operation of the auto-

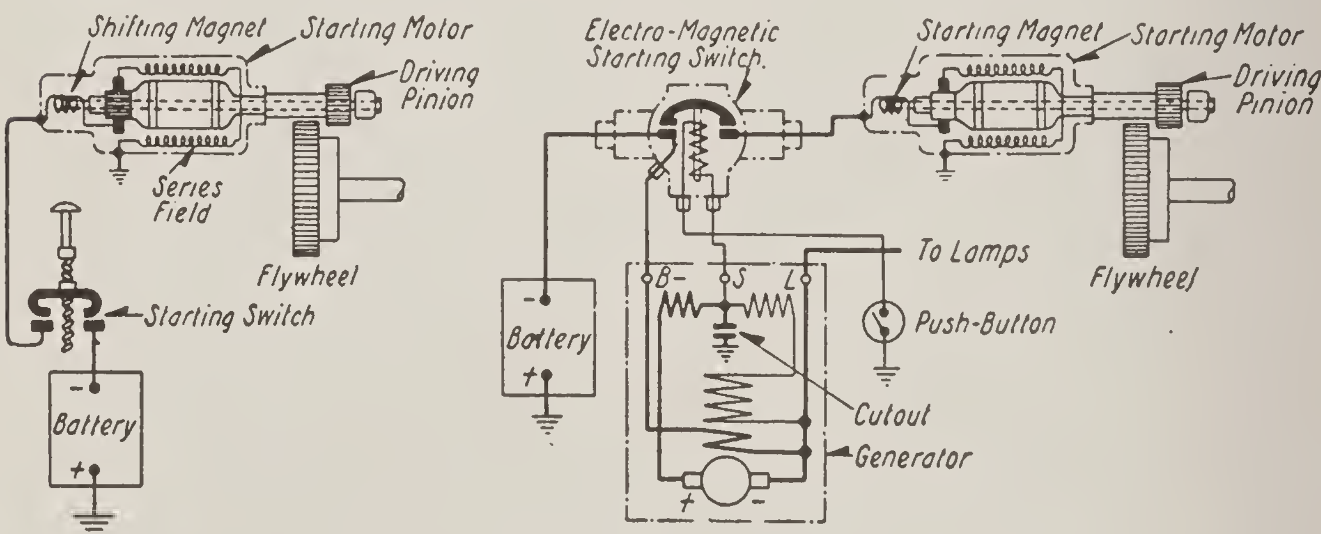


Fig. 366. Wiring Diagrams of Motor Connections for Automatic Electromagnetic Pinion Shift

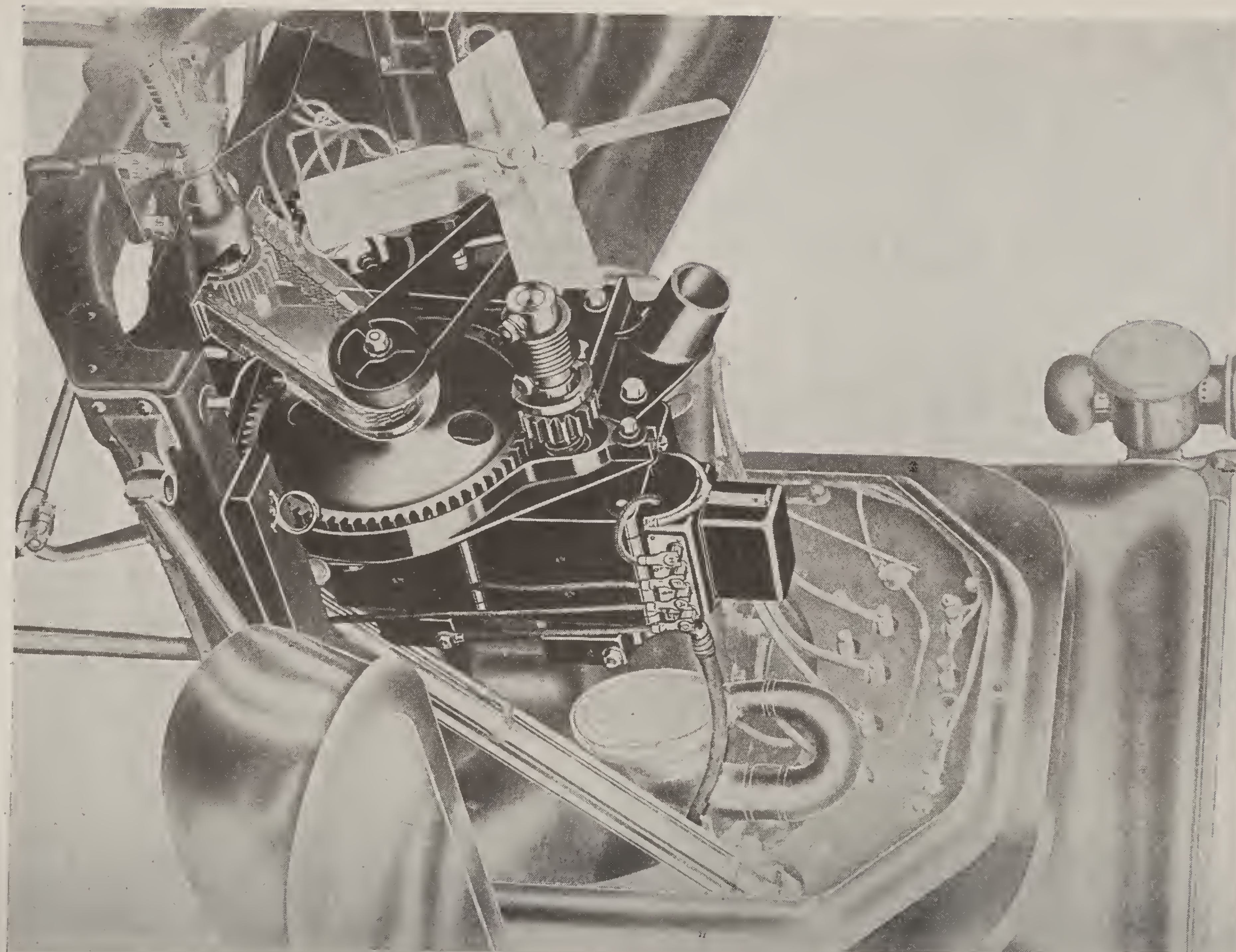
matic engagement. The armature is mounted on a hollow shaft; and on the end of this shaft is carried a splined pinion designed to engage the flywheel gear. This pinion is caused to slide along the shaft by a shifting rod which is attached to the pinion and passes through the hollow shaft. The other end of this shifting rod acts as the core of the shifting magnet and will be recognized as the plunger of a solenoid. When the motor is idle, a spring holds the pinion at the right-hand end of the shaft and clear of the flywheel gear.

As shown diagrammatically in Fig. 366, when the starting switch is closed, the circuit is completed from the negative terminal of the battery, through the switch, the shifting solenoid, the armature, and the series field of the motor to the frame of the car on which the positive side of the battery is grounded. The large amount of current necessary for starting energizes the shifting solenoid suffi-

ciently to overcome the force of the spring so that it draws the shifting rod to the right through the hollow shaft, meshing the pinion with the flywheel gear. When the engine speeds up to the no-load speed of the starting motor, the current in the latter falls off so that the pull of the solenoid is less than that of the spring, and the pinion is automatically disengaged, though the motor will continue to revolve until the starting switch is opened.

Electromagnetic Switch. In principle, the electromagnetic switch is the same as that of the automatic engaging device for the pinion. The movable double-pole contact, instead of being attached to a rod for foot operation, is mounted on the plunger of a solenoid and normally is held open by a spring. This solenoid requires but a small amount of current for its operation and is connected on an independent circuit with the battery. It is controlled by a push button, and when the circuit is closed by means of the latter, the plunger of the solenoid is drawn into the coil against the pull of the spring, thus bringing the contacts together and holding them there as long as the solenoid is energized.

Instructions. *Regulator.* When the generator of the voltage-regulator type fails to charge the battery properly, all parts of the circuits and connections having been examined to determine that they are in proper condition, the regulator may be tested for faults. With the aid of the portable voltmeter, note at what voltage the contacts of the cut-out close or *cut in*, and at what voltage they *cut out* or open. See that the contact points are clean and square so that they make good contact over their entire surfaces when pressed together with the hand. Insufficient charging may be due to the voltage regulator keeping the voltage of the generator below the proper point for this purpose. A voltage adjusting screw is provided to compensate for this. With the voltmeter in circuit and the engine running, turn the screw very slowly and note the effect on the reading. For proper charging the latter should be approximately $7\frac{1}{2}$ to 8 volts, and the screw should be adjusted very gradually to bring the voltmeter reading to this value. This screw is properly set at the factory and is unlikely to need adjustment; so all other possible causes should be investigated before changing it. The instructions for the 12-volt system also apply here, except that for voltage tests the system operates on 6 volts.



FRONT VIEW OF HEINZE-SPRINGFIELD FORD STARTER MOUNTED ON CAR
Courtesy of The John Heinze Company, Springfield, Ohio

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART VII

ELECTRIC STARTING AND LIGHTING SYSTEMS—(Continued)

INSTALLING SPECIAL SYSTEMS FOR FORD CARS

General Instructions. Most of the leading manufacturers who make the starting and lighting equipment for larger cars also manufacture a special type designed for the Ford. Almost without exception these special Ford systems are simple and compact, and everything necessary to install them on the machine is provided by the maker of the apparatus. Where the system is to be installed, either by the owner of the machine or by the local garage man whose electrical experience is limited, the choice of the most suitable system often is decided by the ease with which it may be installed. In practically every case this necessitates the removal of the radiator, radiator brace rod, hose connections, fan, fan pulleys and belt, cylinder head, and in some cases the timing-gear housing. In the majority of instances the ground connection of the headlights—which is soldered to the back of the radiator on 1915 and subsequent models provided with electric headlights supplied by the Ford magneto—must be discarded altogether, as the lights are to be supplied by the storage battery. In cases where it is necessary to remove the timer (this must be done when the timing-gear housing has to be removed), both the timer and the carburetor should be adjusted for efficient running before starting to dismantle the engine, and if the latter is turned over while the timer is off, the ignition timing must be readjusted when the timer is put back. As the removal of all the parts mentioned is a simple matter fully covered in the Ford instruction books and familiar to practically every garage man in the country, they are not repeated here.

In starting to install any system, one of the first precautions to take before attempting to dismount any of the parts of the engine is to check over the list of parts sent with the outfit with those actually received. The reason for this is that it at times an essential part has been omitted, and this is not discovered until a large part of the labor of dismounting the engine has been carried out; the work must be done all over again or the engine kept dismounted until the missing part arrives.

GENEMOTOR

Chain-Driven Type

Mounting Starter. Drain the radiator and remove it with the water-pipe and elbow connections from the engine; remove the starting-crank claw and take out the starting crank; take the fan-belt pulley off the engine shaft, the fan and the supporting arm from the cylinder casting, the primer rod from the carburetor and timer-advance rod; take out the second and third right-hand crankcase bolts *A*, Fig. 367. Clean the engine thoroughly to insure proper seating of the bracket and with a file remove any high spots, or fins, on the casting that would interfere. Mount the unit on the engine, first inserting the base bolts and then the water-flange bolts with elbows. Place gaskets each side of the bracket. Use the plain washers between the engine case and the foot of bracket *D* to insure proper support and alignment with the water-pipe connections *E* and *F*. Attach the driving sprocket *G* to the crankshaft, using the new pin *H* supplied. It may be necessary to bend the crankcase nose slightly at *I* to provide clearance for the chain on the right side and to chip off part of the rivet heads under the sprocket. There should be at least ½-inch clearance at all points around the sprocket after the chain is in place.

Replace the starting crank and claw and turn the engine over slowly by hand to feed the chain on to the sprocket. Connect the ends of the chain together, noting the arrows on the side of the chain, which show the direction in which it must rotate. Before connecting the chain, the Genemotor fan pulley with internal spring should be removed as a unit to prevent the possibility of changing the spring adjustment. Care should be taken that the slot in the spring support into which the forks of the pinion assemble clears the key. These can

be brought into line by holding the pinion and turning the fan pulley in a counter-clockwise direction (to the left). Loosen the clamping

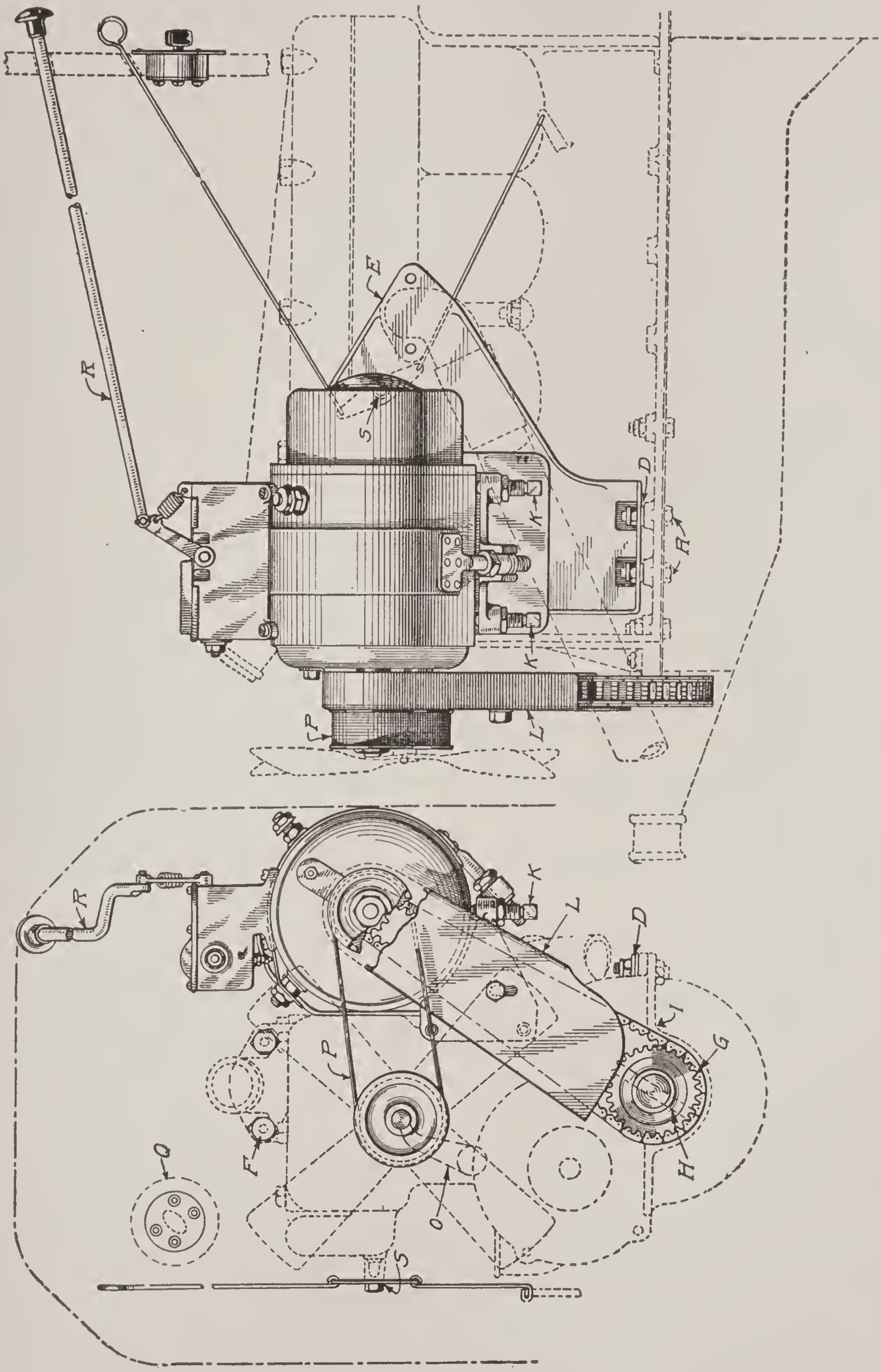


Fig. 367. Working Drawing for Installing Chain-Driven Genemotor
Courtesy of General Electric Company, Schenectady, New York

strap and tilt the whole unit slightly to receive the chain. Apply a straightedge, as shown in Fig. 368, and align the sprocket accurately,

making sure that the Genemotor shaft is parallel with the crankshaft and that the pinion with bushing is pressed against the ball bearing. Allow a slight amount of slack in the chain when adjusting by means of the two set screws *K*, Fig. 367, which raise the unit in its cradle. When such adjustment is made, be sure that the starting switch is in an upright position on top of the motor and tighten the clamping strap. Grease the chain thoroughly and attach the chain guard *L*. Replace the pulley with spring locking with pinion, as when received. Assemble the clamp pulley supplied for driving the fan on to the regular fan pulley, reducing the flanges of the latter by filing, if necessary. Replace the fan and the bracket *O* on the engine. If the fan blades should not clear the Genemotor pulley, twist them slightly with a wrench and bend out the tips of the fan blades. Put back the old fan belt, but do not adjust it too tightly. Replace the timer rod, bending it as necessary to make sure that it clears the chain properly. Turn the engine over by hand to make sure that the chain is free and properly adjusted; it is important that the chain should not touch the nose piece or forward end of the crankcase or the side rivet heads. Before replacing the radiator and hose connections, it is advisable to run the engine a few minutes to note alignment, clearance, and operation.

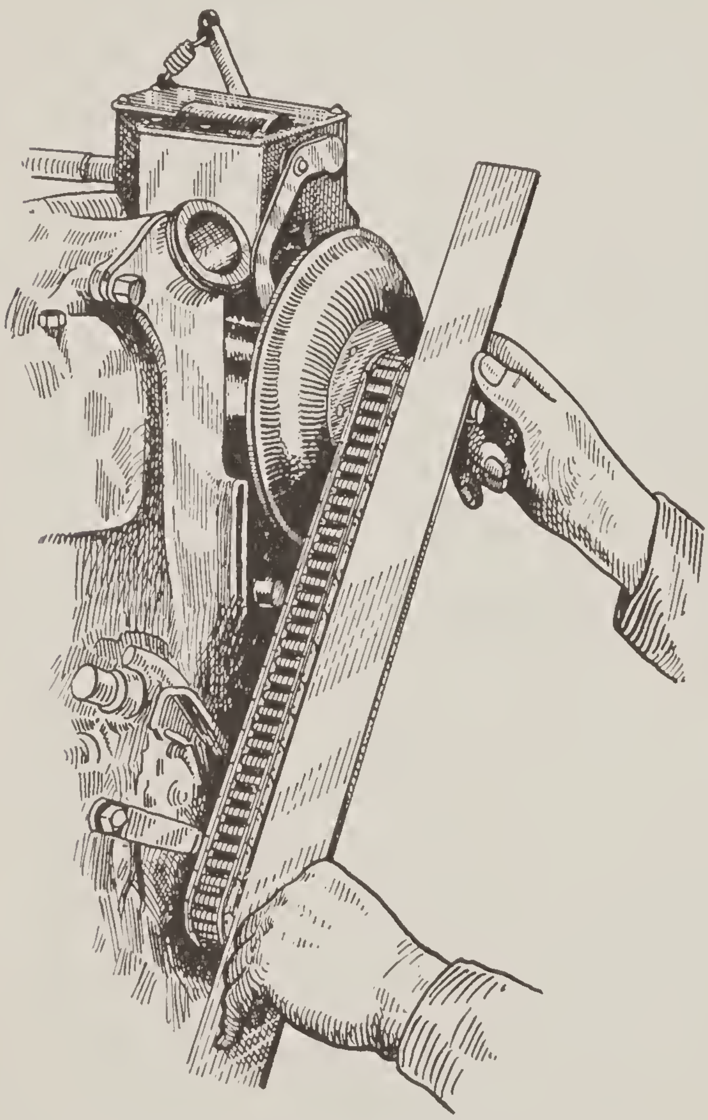


Fig. 368. Method of Checking Chain Alignment with Straightedge

The dashboard is to be drilled for the lighting switch *Q* on the right-hand side, as viewed from the seat, directly under the carburetor adjustment and for the starting-switch rod *R* on the left-hand side close to the coil box. On the sedan, coupelet, and 1915 models, the

lighting switch may be placed on the upper left-hand corner of the heel board under the driver's seat, or it can be mounted on the dash close to the speedometer. Mount the primer lever and the special washer *S* under the second manifold stud nut, passing the original rod through the dashboard.

Wiring. All of the leads are marked for identification, and the wiring diagram will be readily understood from Fig. 369. The battery box should be mounted on the right-hand running board so as not to interfere with entrance to the car, and so that the hole in the bottom of the battery box overhangs the running-board shield, through which a new hole must be cut. The battery leads, protected by the circu-

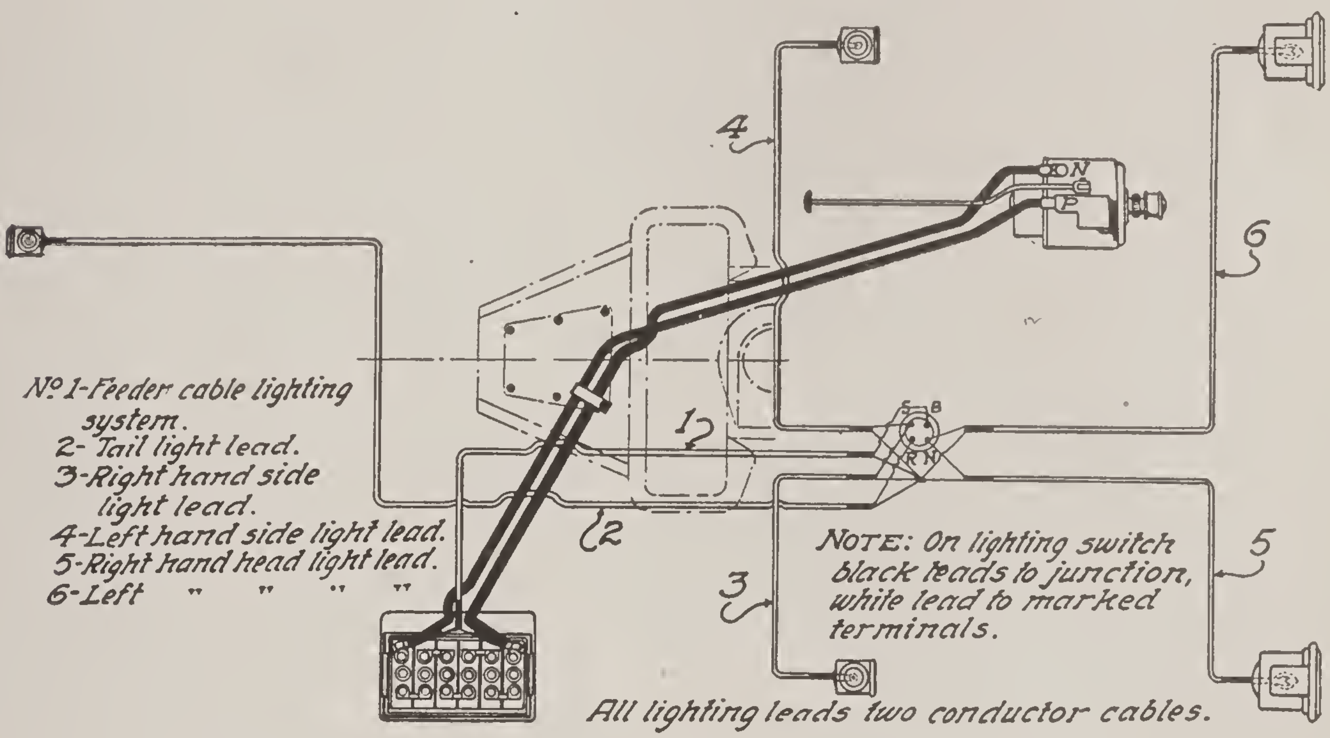


Fig. 369. Wiring Diagram of Genemotor Ford Installation

lar loom supplied for the purpose, should be run through this hole. The motor cables supplied with this outfit are to be run diagonally across the transmission case of the engine from the unit to the battery. Where they cross the transmission case, these leads are supported by a steel clip furnished for the purpose, the clip being secured under the right-hand screw holding the transmission cover in place (next to the dash). In installing the leads, the screw in question should be removed, the clip placed over the wires, and all secured by returning the screw through the clamp to its original position. The two hold-down straps are to fasten the battery box securely to the running board, the clamps fastening to handles of the battery case and passing through the running board. Where wiring passes through holes cut

in sheet-iron parts, it should be protected by extra taping to avoid danger to the insulation from chafing. Make certain that all connections are clean, are properly made as shown on the wiring diagram, and are clamped tightly.

On the 1915 and subsequent models, on which the headlights are electric and are supplied with current from the magneto, it will be necessary to discard the wiring and switch connections and to do away with the ground connection soldered to the back of the radiator, as

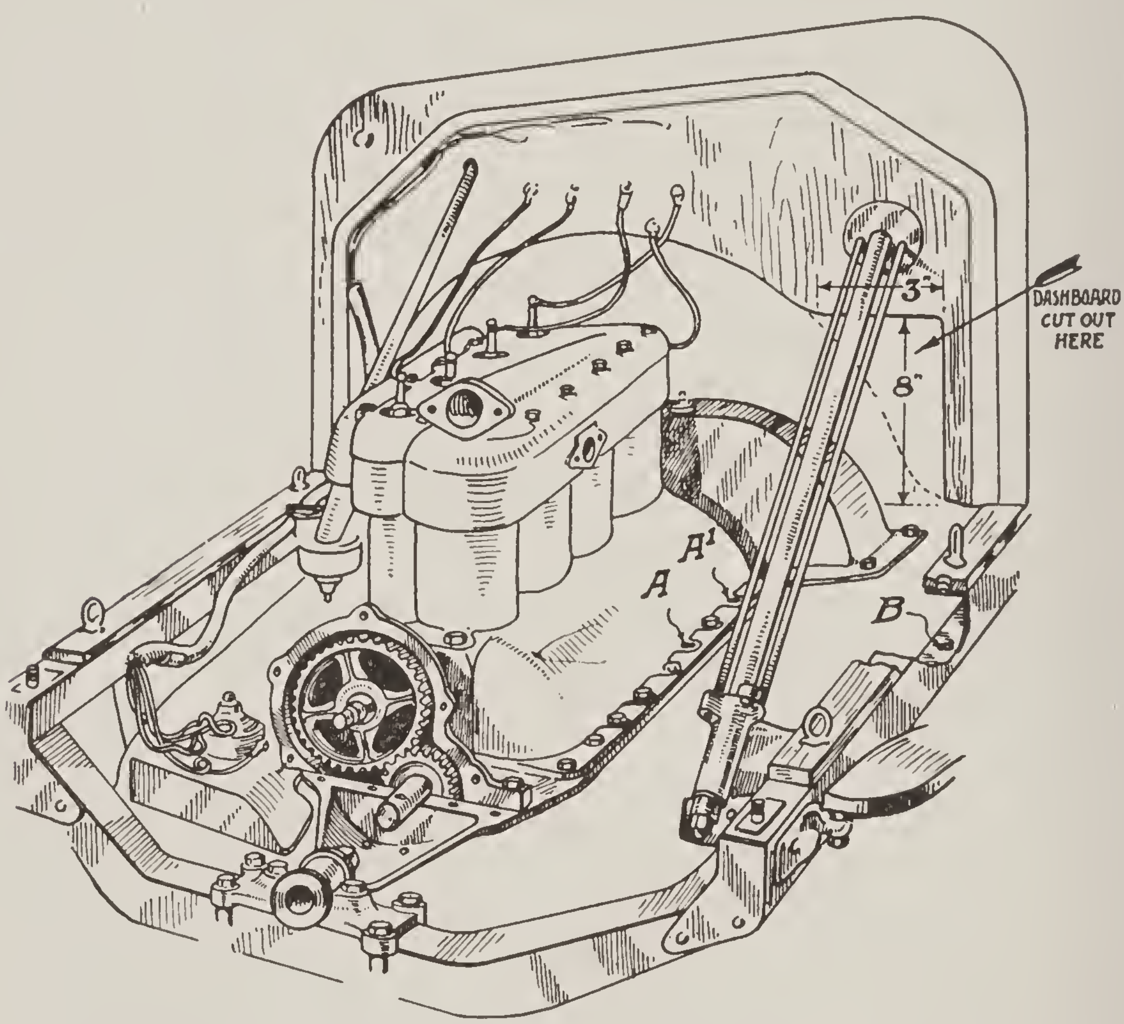


Fig. 370. Ford Frame Stripped for Mounting Shaft-Driven Genemotor

the new system is of the two-wire type throughout, and all the lamps are fed with current from the storage battery through a lighting switch on the dash.

Operation. The Genemotor is a single-unit type, the same machine performing the functions of both generator and starting motor. The starting switch and the reverse current relay, or automatic cut-out, are in a small housing mounted directly on the machine. Starting is effected by pushing the switch rod forward. The switch will open automatically when the rod is released. During the first hundred miles, it will be necessary to watch the chain carefully and

take up the slack as the links seat themselves in the sprockets. Whenever it shows excessive slack, the chain should be tightened so that it will not deflect more than $\frac{5}{8}$ inch from a straight line by the pressure of the fingers. It is very essential to the life of the chain that it be not allowed to run too slack. The occurrence of any undue amount of noise in operation is a sign that the chain is too slack. The chain must always be kept sufficiently tight to prevent striking the guard or the nose of the crankcase and it is very essential that it be greased every two weeks.

Shaft-Driven Type

Preliminary Adjustments. Before dismantling the engine, be sure that it is in good running condition and that the carburetor is properly adjusted. Remove the radiator with the water-pipe and elbow connections, starting crank and claw or dog clutch, fan bracket complete with fan and belt, fan-drive pulley on crankshaft, timer or commutator complete, timing-gear cover (leave paper gasket and engine bolts *A* and rear sill bolt *B*, Fig. 370). Cut out the dashboard as shown. Remove the felt packing rings used around the crankshaft and camshaft from the old timing-gear cover, or housing plate, and place them in the new timing-gear cover supplied (sometimes referred to as the "cylinder front cover"). Reassemble, putting the new timing-gear cover in place, using bolts *E*, *F*, *G*, and *H* in the holes indicated, Fig. 371, and using lock washers. Leave the bolts slightly loose. Throw the hand-brake lever into middle position and push the crankshaft back as far as it will go. Assemble the split hub *J* on the crankshaft, inserting the hub pin through a set of holes in the hub which give not less than $\frac{1}{32}$- and not over $\frac{3}{32}$-inch clearance between the back of the hub flange and the timing-gear housing.

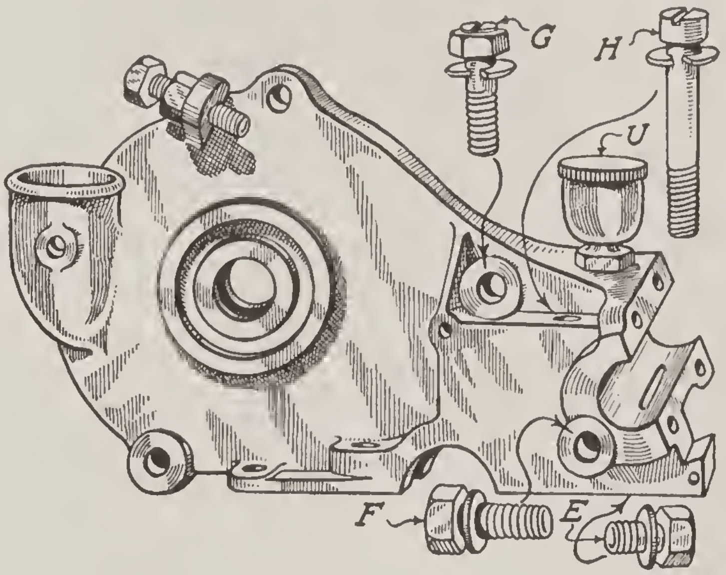


Fig. 371. Timing-Gear Cover Assembly

Drive the hub pin *K*, Fig. 372, into the crankshaft, being careful that the ends are an equal distance below the surface of the threaded

portion of the hub. Chisel off parts of the rivet heads XX, Fig. 373, in the pan of the engine and assemble gear ring L and place on the hub. In some cases it may be found necessary to bend out the side of the nose pan slightly by means of a wrench, as shown, to obtain the necessary clearance for the gear ring, which must not be less than $\frac{1}{64}$ inch at any point. The recess in back of the gear ring will facilitate its insertion past the front of the crankshaft. Fasten the gear ring to the hub flange with the three screws and lock washers provided.

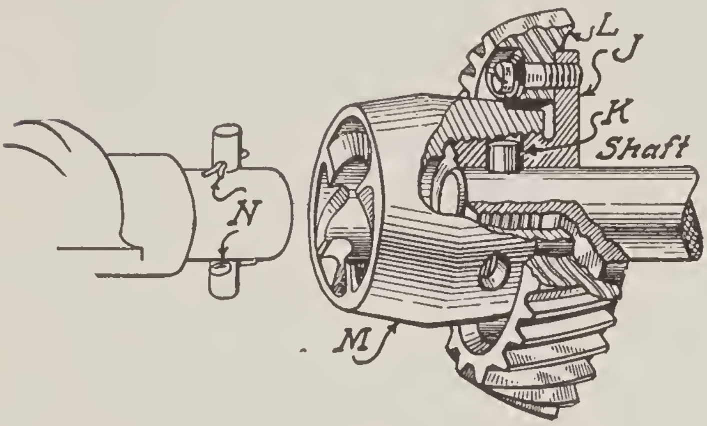


Fig. 372. Fitting Split Hub on Crankshaft

Throw the hand brake in the extreme forward position to lock the engine and screw the hub nut M, Fig. 372, on the hub, tightening it with a $\frac{3}{8}$-inch steel rod inserted in the holes provided. Replace the

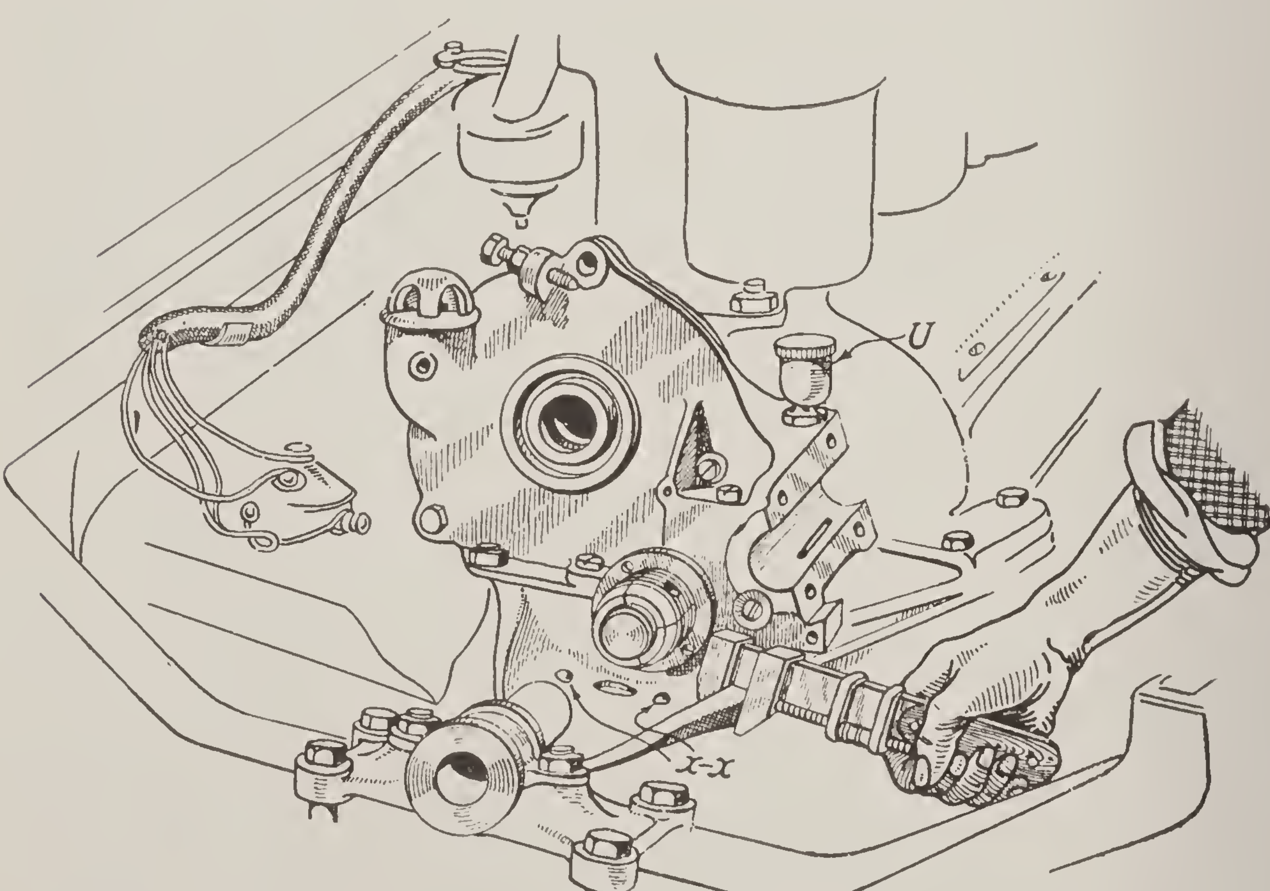


Fig. 373. Mounting Gear Ring and Adjusting Nose Pan in Genemotor Ford Installation

starting handle minus its original starting ratchet, or dog clutch, using in its place the ratchet pin supplied, and retain it in place with the cotter pins N supplied, Fig. 372. Remove the leather coupling P,

Fig. 374, complete from the end of the pinion shaft. Unscrew the bearing-housing cap *Q*, Fig. 375, from the timing-gear cover and lay

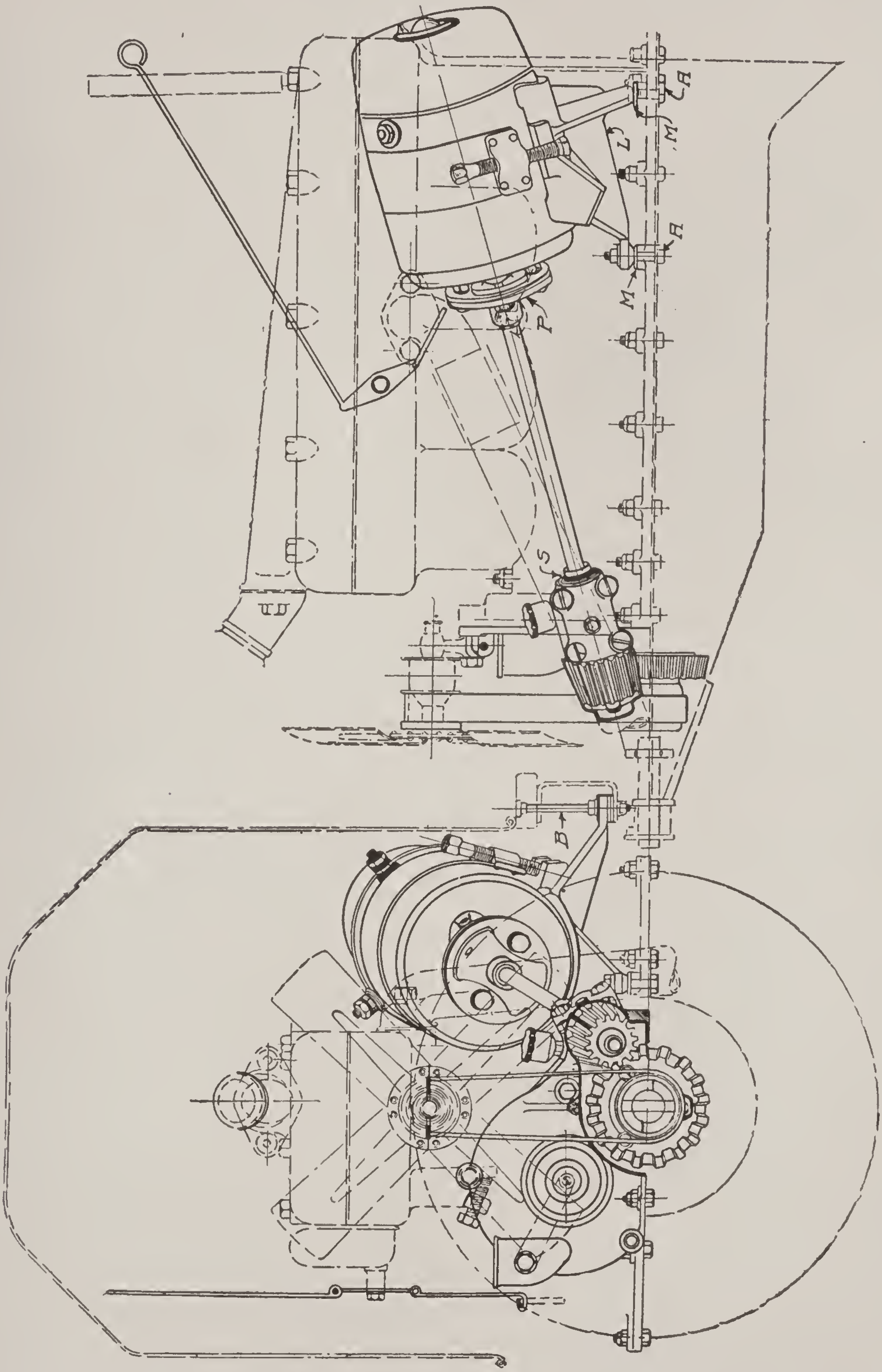


Fig. 374. End and Side Elevations of Motor and Driving Shaft
Courtesy of General Electric Company, Schnectady, New York

the bearing lining with pinion shaft in place. *The coupling is keyed to the armature shaft and the drive shaft. Always remove the coupling complete by driving it off either shaft. Do not separate the leather from the*

flanges. Be sure that the lining screw R, Fig. 375, in bearing the cap enters the hole in the bearing lining before replacing the cap, and that the shaft does not strike the base of the engine casting, which would spring the shaft. If necessary, file away the corner of the engine base to clear the shaft by at least $\frac{1}{32}$ inch.

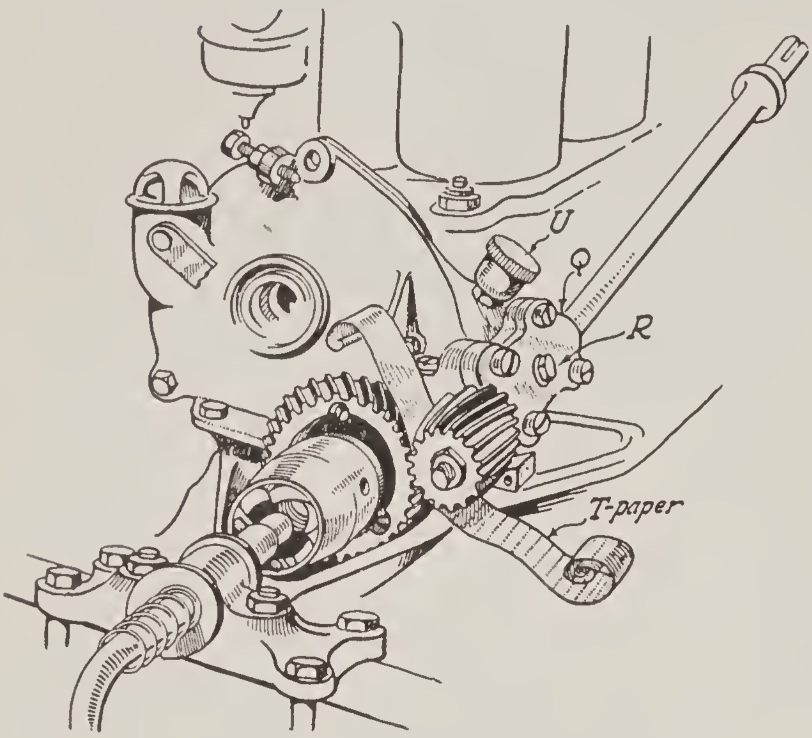


Fig. 375. Adjusting Driving Pinion

Adjustment of Gears. The steel gear must at all times run on the *fabroil* teeth of the pinion and not on its steel shrouds. To accomplish this, rearrange the steel pacers *S*, Fig. 374, on the pinion shaft, placing them more or less forward or back of the lining, as may be necessary. *In no case should any washers be left out.* Throw the hand-brake lever into middle position and turn the engine over with the crank, feeding in between the gears a strip of the paper *T*, Fig. 375, supplied for the purpose. Lightly tap the timing gear to the left as far as necessary to mesh the gears tightly. Tighten up the retaining bolts. Turn the engine over again to feed the paper out. The paper should be evenly marked but not cut. If the paper shows signs of cutting through at any point the gears are meshed too tightly. *Do not, under any circumstances, place any shim between the bearing lining and its supporting housing.*

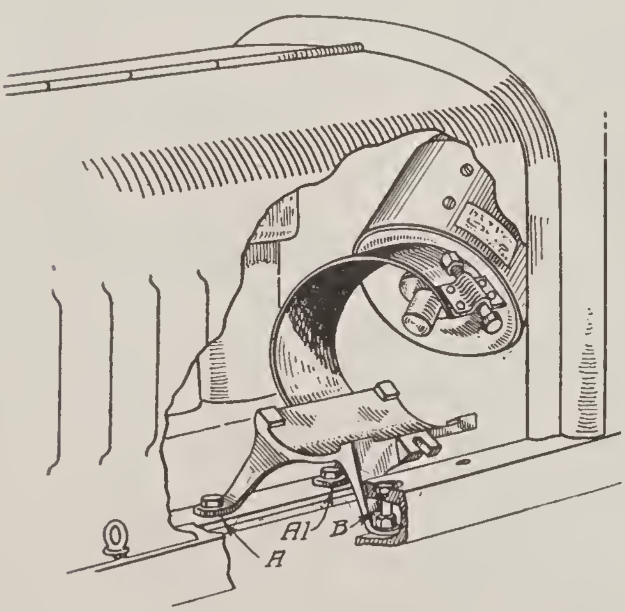


Fig. 376. Motor Cradle Assembly

Mounting the Genemotor. Assemble the motor cradle in place, Fig. 376. Place a $\frac{1}{8}$-inch spacing washer under the leg nearest to the transmission cover and insert the special bolt *A1* with the lock washer from the underside of the car but leave it slightly loose.

Put in place the front leg bolt *A* and the new sill bolt *B* with lock washers but do not tighten up. Insert the Genemotor from the rear side of the dash through the hole previously cut for the purpose, sliding it on to its cradle, and clamp in place with the steel strap, leaving about $\frac{3}{8}$-inch space, Fig. 377, between the motor shaft and the pinion shaft. The flat space on the motor body should be parallel to the iron dash support.

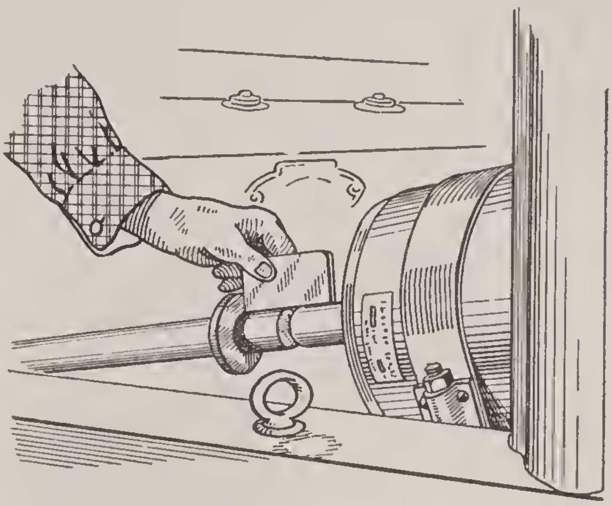


Fig. 377. Checking up Alignment of Motor Shaft and Pinion Shaft

Motor Alignment. Raise the front leg and the sill leg of the cradle by a suitable thickness of spacing washers supplied until the ends of the shaft are in line, utilizing the clearance in the bolt holes to obtain the sidewise adjustment. *The ends of the shafts must be lined up accurately to within $\frac{1}{64}$ inch, or the bearing will overheat and be destroyed.* Check the line-up as shown in Fig. 377. When the

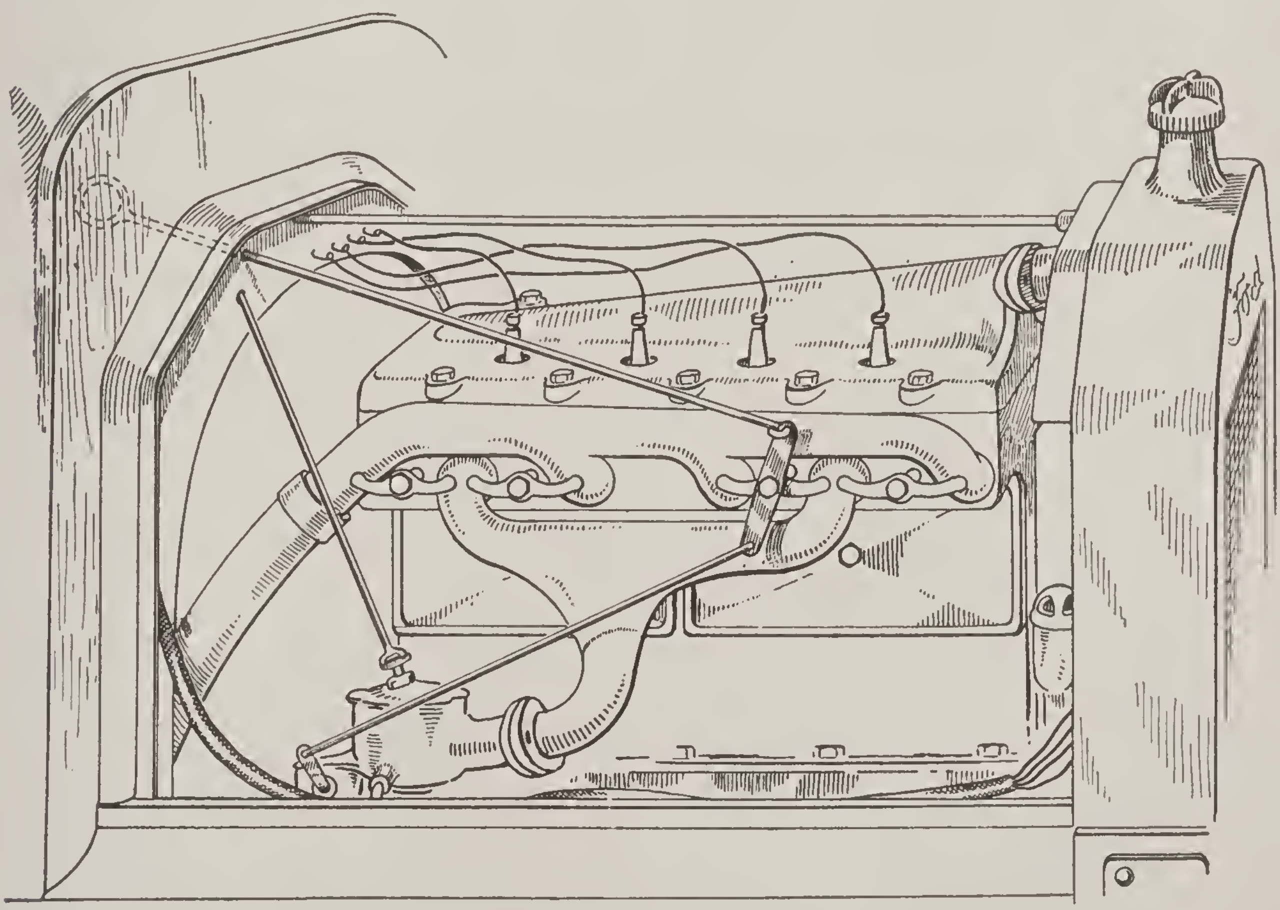


Fig. 378. Priming Rod and Lever Adjustment

adjustment is satisfactory, tighten all the bolts, setting up the lower nut on the sill bolt first and re-check the line-up; if necessary,

readjust. Remove the bearing cap and the pinion shaft. Assemble the leather coupling on the pinion shaft, then assemble the other end of the coupling on the motor shaft; both should be a light drive

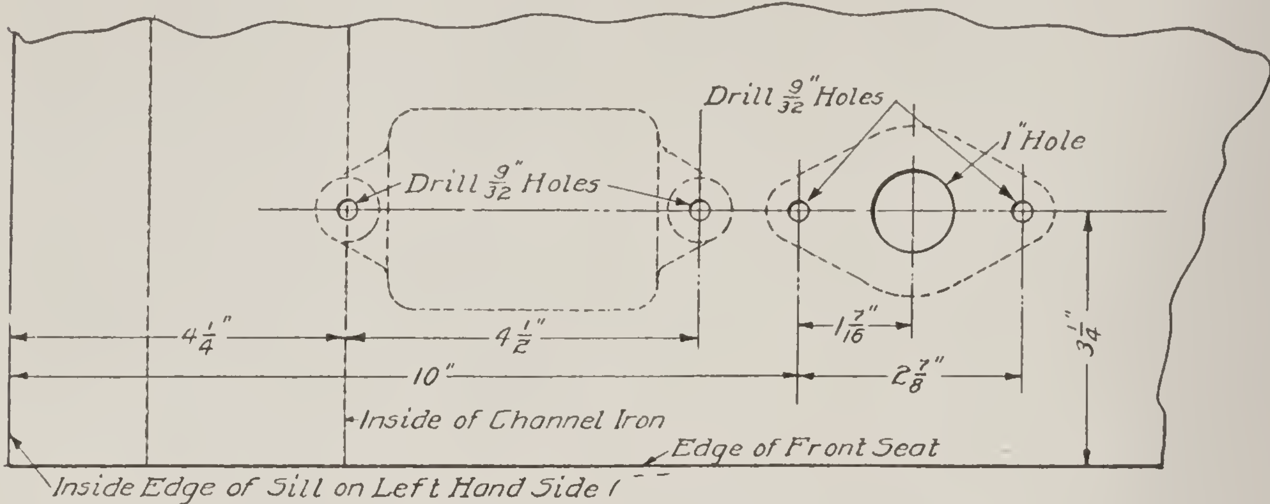


Fig. 379. Layout on Under Side of Heel Board for Starting Switch and Cutout

fit. Fill the recesses in the bearing lining and bearing with a good grade of non-acid grease. Replace the lining and shaft in the housing and secure the cap in place. Fill and fully compress the grease cup *U* twice to assure that the grooves and pockets are filled, Fig. 373. Also thoroughly grease the gears and assemble the gear guard with its two screws and lock washers. "Gredag No. 32-inch" (semi-liquid graphite grease) or its equivalent in powdered graphite lubricant is recommended for this purpose.

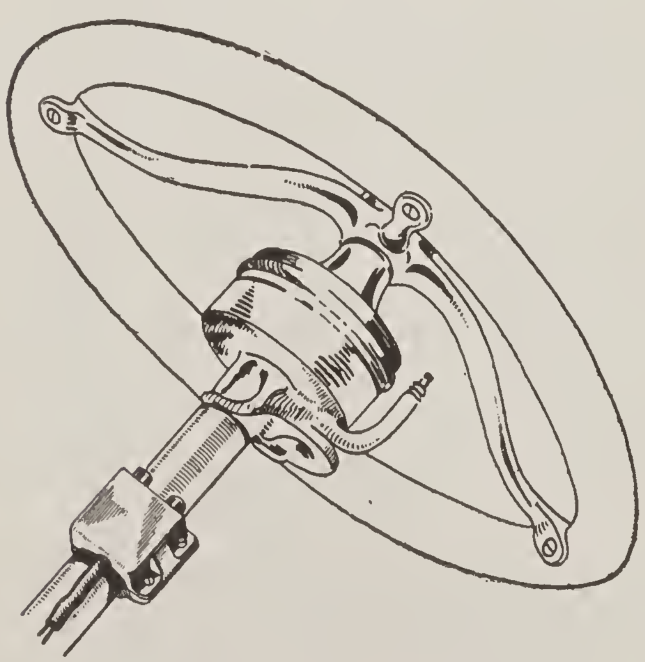


Fig. 380. Lighting Switch Mounted on Steering Post

Replace the Ford commutator, or timer, setting it with the steel brush upward when the exhaust valve of cylinder No. 1 is closed, as mentioned in Ford ignition instructions. Fit the two-piece fan pulley around the neck of the Ford fan pulley and secure it with screws and lock washers provided. Reassemble the fan and bracket complete, using a new 1-inch belt, which is driven from the pulley on the gear hub nut *M*, Fig. 372. Replace the radiator and the water connections to the engine, using a special bolt for the elbow connection nearest the genemotor. Replace the spark-advance rod,

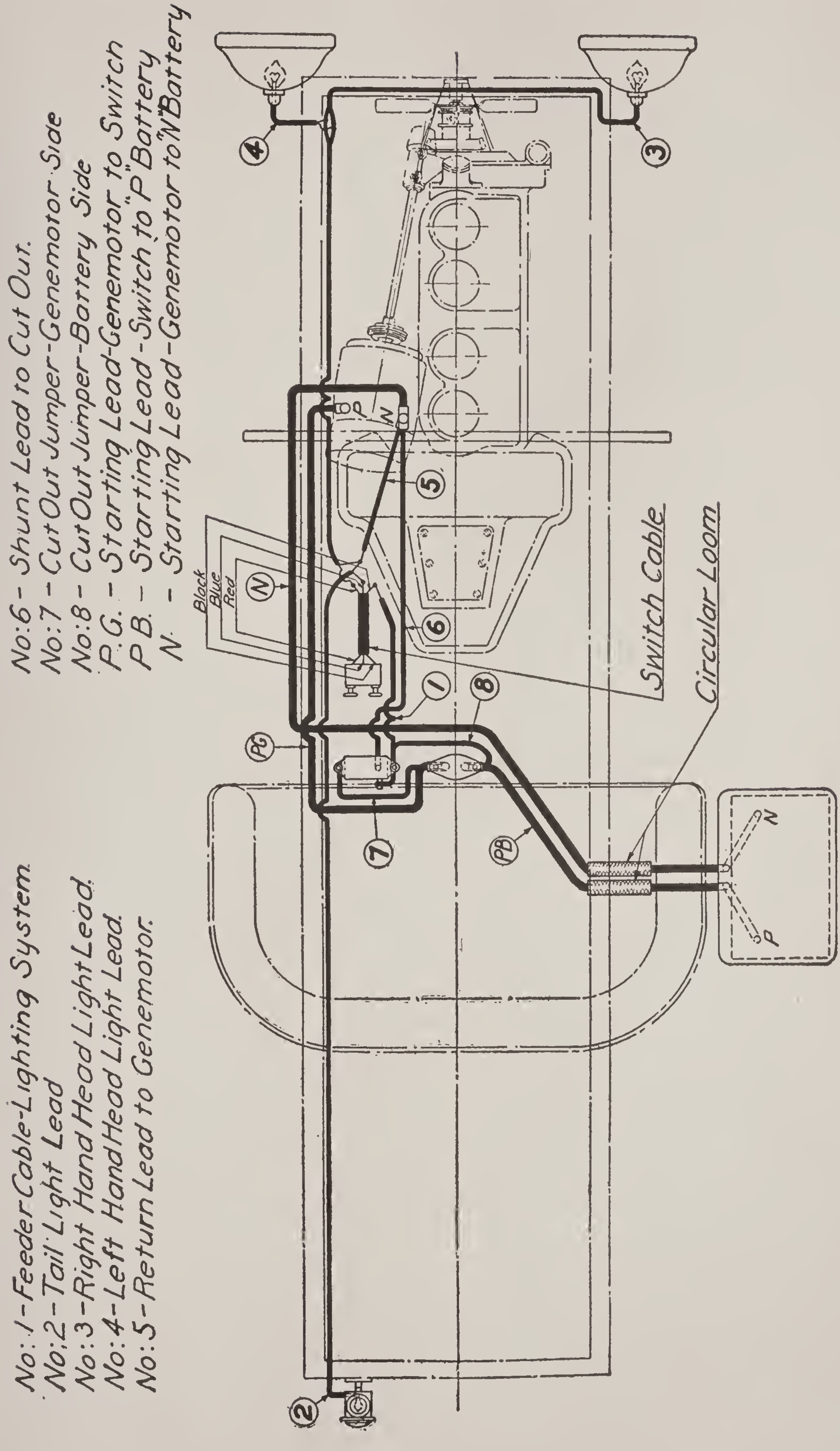


Fig. 381. Wiring Diagram for Head and Tail Lights
Courtesy of General Electric Company, Schenectady, New York

bending it to pass over instead of under the water connection, before fastening it to the timer. The throttle rod must be turned upside down and assembled with cotter pins toward the dash to clear the coupling. Attach the primer rod and lever, as shown in Fig. 378, using part of the Ford primer rod originally coming through the radiator. Mount the starting switch and cut-out on the underside of the heel board, Fig. 379. The rubber floor mat must be cut to fit the foot plunger.

Mount the lighting switch on the steering column, Fig. 380, clamping the cable attached to it between the recess in the switch box

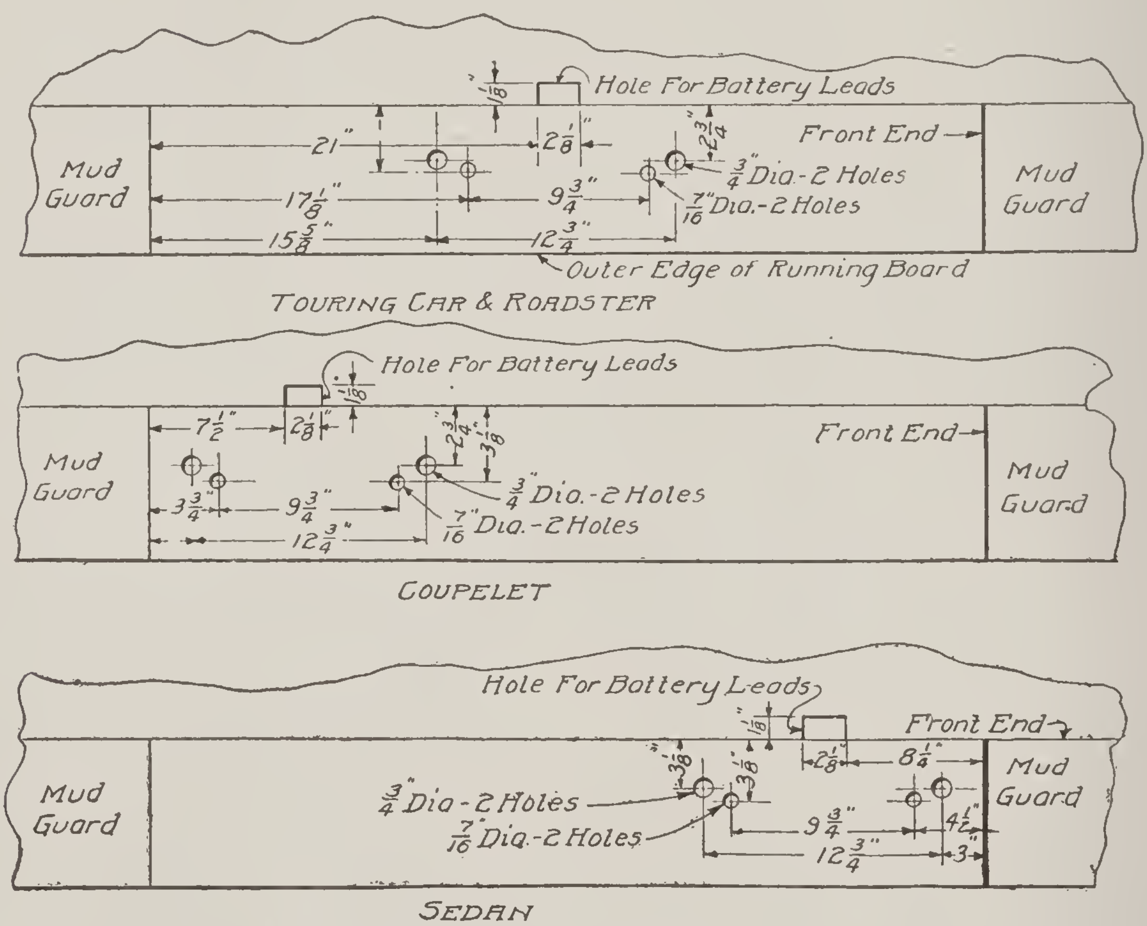


Fig. 382. Layout of Right Running Board for Mounting Battery Box on All Ford Models

and column, and wire up the head and tail lights, Fig. 381, with leads supplied. Each lead is tagged to correspond with the wiring diagram. Drill holes in the right-hand running board for the battery box, Fig. 382, including the slot in the side panel where the main cables will pass through, and bolt the battery box on to the running board. Connect the Genemotor to the switch and cut-out, Fig. 381, placing on each battery cable a piece of the circular loom (supplied) at the point where the cables pass through the slot cut in the side panel, securing the circular loom in place by taping each end of the loom

to the cable. Each cable is tagged to correspond with the wiring diagram. Place the battery in the battery box, allowing it to rest on the wooden supports (supplied) and clamp through the box to the running board with battery clamps. Connect the negative lead to the negative terminal of the battery, then touch the positive lead to the positive terminal. If no spark occurs when the positive terminal is touched, connect up permanently; should a spark be noticed, it indicates a short-circuit or a leak in the system, and the wiring will have to be gone over carefully to correct it before connecting up permanently, otherwise the battery will discharge itself. Turn the engine over slowly by hand to see that everything is clear. The starter and the lights are now ready for use.

Operating Instructions. *Whenever it is necessary to remove the battery for any reason, never operate the generator unless its terminals are first connected together with a copper wire or cable, otherwise the generator will overheat and injure its windings. The lights cannot be used with the battery off the car. Never operate the generator with the small regulating brush removed or with its contact surface reduced, as normal charging current will not be generated, and the battery will not charge properly.*

In extremely cold weather, it is advisable to "break away" the engine by hand, giving the crank a few turns to loosen the lubricating oil on the pistons and bearings, thus preventing undue drain on the battery. The starter is designed to spin the engine at a speed sufficient to insure easy starting on the Ford magneto. If the engine does not fire promptly, pull out the priming rod at the forward end of the radiator and turn the engine over two or three times by hand before closing the starter switch again. Should the engine still fail to start, examine the timer, squirting a liberal supply of one-fourth kerosene and three-fourths lubrication oil into it; see that there is plenty of gasoline in the tank and that it is reaching the carburetor. Turn the carburetor, or gasoline-supply adjustment, on the dash up (to the left) to insure a liberal supply of gasoline in cold weather. When an easy starting point of this adjustment has been found, it should be marked by filing a nick or arrow on the small brass wheel; turning the latter with the arrow upright will then insure easy starting in cold weather. After the engine has run a short time and become warmed up, the wheel can be turned down 15 to 20

degrees (to the right), and several more miles per gallon will be secured. When the engine does not get under way promptly, do not exhaust the battery unnecessarily by continuing to run the starter. In any case where the engine fails to start the first time and examination shows everything to be in good condition, operate the starter intermittently a few seconds at a time but not continuously.

Failure to Start. When the starter fails to turn the engine over, try cranking by hand to make sure that the crankshaft is free to revolve before attempting to make any adjustments. If it turns freely by hand but the starter cannot move it, test the condition of the battery charge with the hydrometer. In winter, particularly, cars are often run for days at a time on very short runs with frequent stops and starts, and under such conditions the battery is likely to become exhausted, as the average charge is less than the requirements imposed upon it by the great number of starts made. In such cases, it may be necessary to give the battery a special charge from an outside source or by running the engine with the car standing.

Ammeter. A recording instrument is not regularly supplied as a part of the system, since the generator is fitted with an inherent type of regulation having no moving or vibrating parts, so that as long as the system is kept in good condition, charging is assured. Where the owner considers the addition of an ammeter desirable as a means of checking the operation of the system, the instrument can readily be added by removing the jumper wire on the starting switch and connecting the ammeter leads across these two posts. The lamps recommended for use with the system are 12- and 14-volt 15-c.p. Mazda or 24-c.p. nitrogen (not desirable, as it causes too much glare), and 12- and 14-volt 4-c.p. Mazda for the tail light. For care of battery, see sections on Battery Charging and Maintenance.

GRAY & DAVIS

Installation. *Preparing Engine.* Remove the radiator, disconnecting the ground wire from it; disconnect the wires from the head lamps and remove the head lamps and supports. Take off the bracket and fan, Fig. 383, and turn the engine by hand until the pin *2* in the fan pulley is straight up and down; remove the pin from the jaw clutch and remove the starting-crank *4*, belt *5*, and the cotter pin, *3;* take the pin from the fan pulley and remove the pulley *6*. Remove

the second, fourth, and fifth bolts from the crankcase flange *7*, the left and front bolt from the side-water connections *8* and *9*, as well as the second cylinder-head bolt *10*.

NOTE—The numerals refer to the parts to be removed or replaced, as well as the sequence in which the operations are to be carried out, as shown on the sketches. Each illustration, however, has its own series of the same numbers, which should not be confused with those on other views.

Lay the chain *1* in the rear of the engine support around the crank-shaft, Fig. 384, and then place the original starting-crank jaw

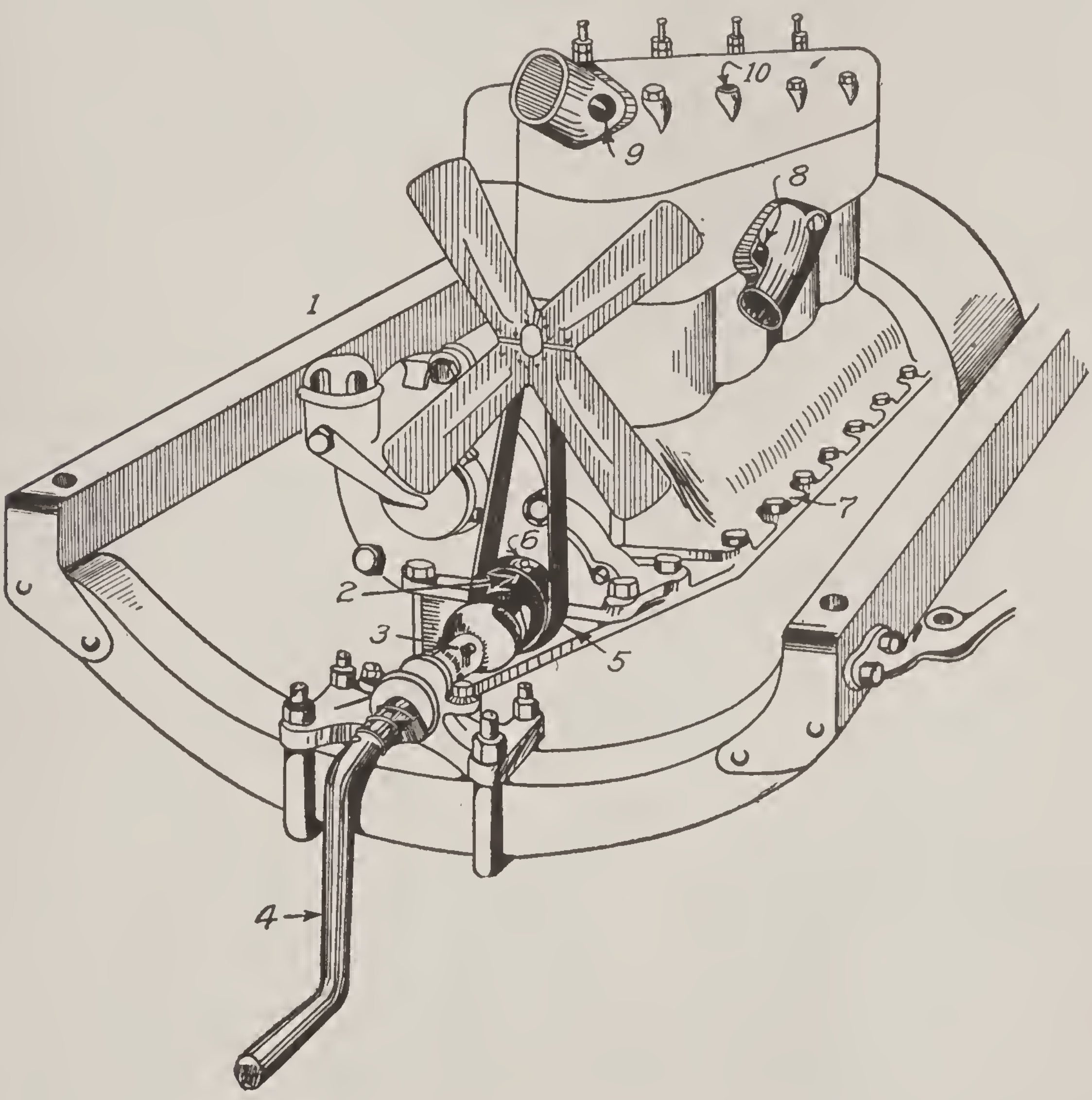


Fig. 383. Preparing Engine for Mounting Starting Unit
Courtesy of Gray & Davis, Boston, Massachusetts

clutch *2* inside of the crankshaft sprocket. Place the crankshaft sprocket *3* on the crankshaft and put the new belt *4* around the pulley on the crankshaft. Secure the sprocket with the new pin *5* (supplied) and then connect the starting crank in its original position. Secure the jaw clutch to the starting crank with pin *7*.

Mounting Starter-Generator. In Fig. 385 is shown the starter-generator unit, for which note the following instructions: See that

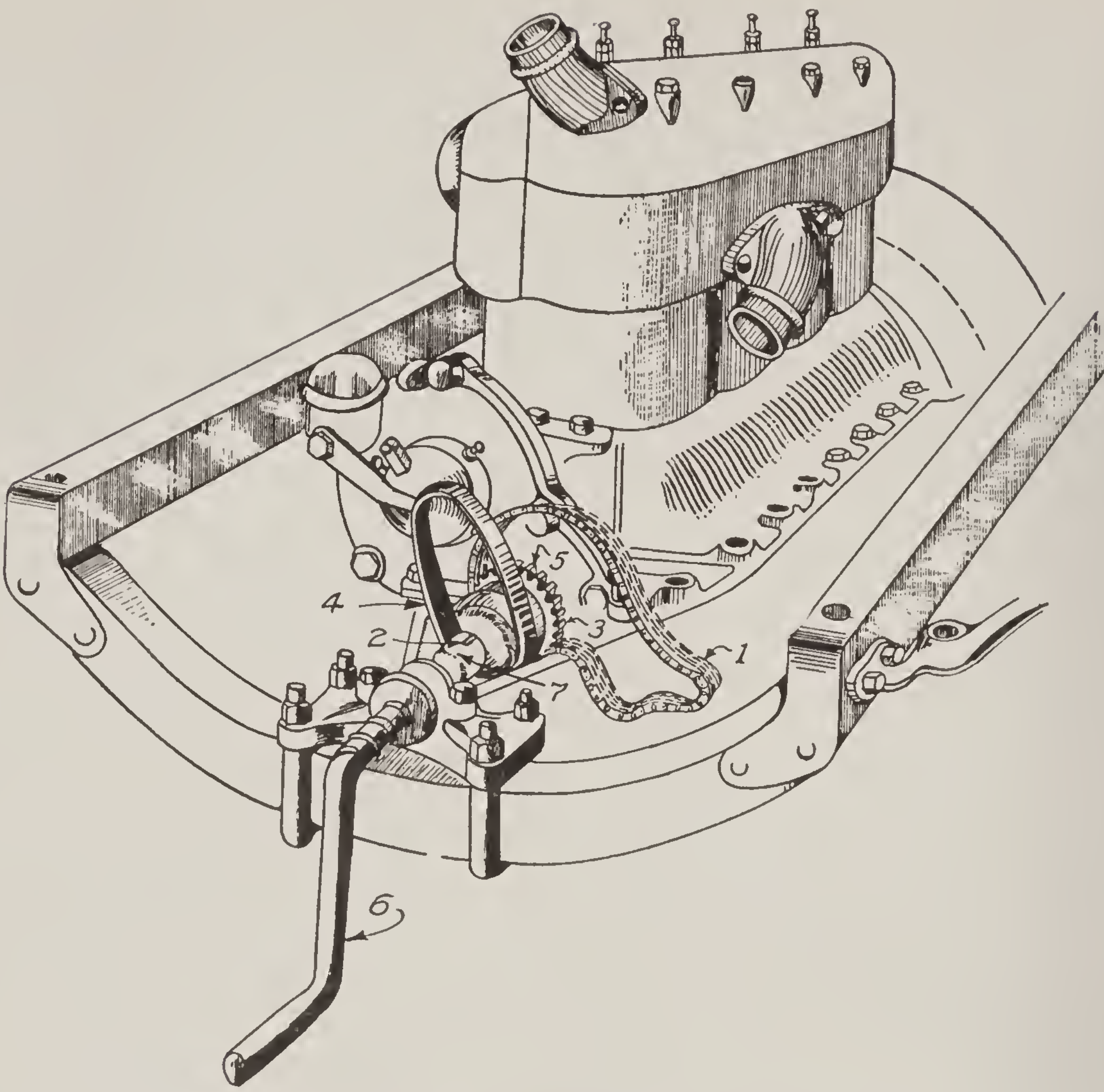


Fig. 384. Putting Driving Chain on Crankshaft Sprocket in Gray & Davis Ford Installation

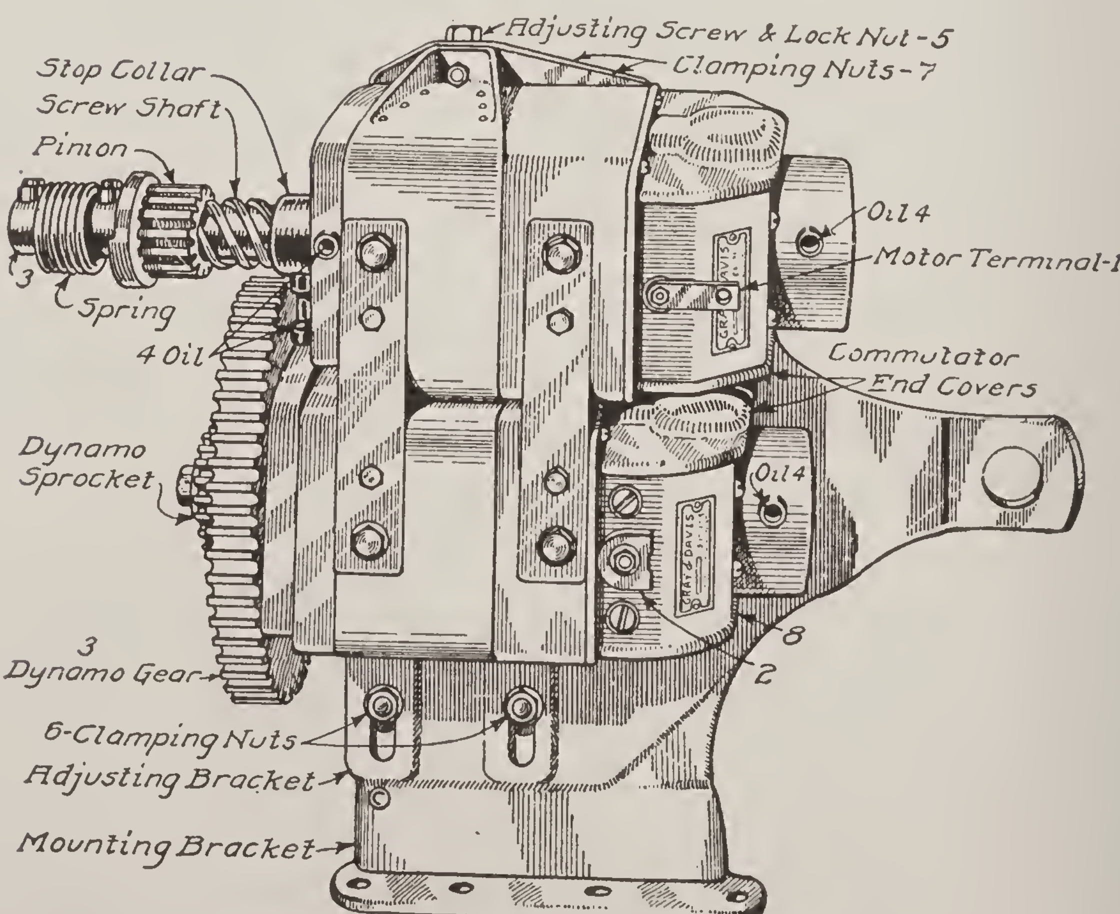


Fig. 385. Details of Gray & Davis Generator Unit for Ford Starter

the motor terminal *1* is free from contact with any other metal; also that the dynamo terminal *2* and insulation are not injured. Test the shaft and gears *3* to see that they turn freely, and then fill the oil cups *4* with oil.

Release the top adjusting screw *5*, also two lower clamping lock nuts *6* (front), as well as the two upper clamping lock nuts *7* (rear) and the single middle clamping lock nut *8* (front). The units must be in the lowest position possible on the bracket before placing it on the car. In Fig. 386 is shown the starter-generator unit in place on the engine with the bolts and nuts all tightened. This is carried out as follows:

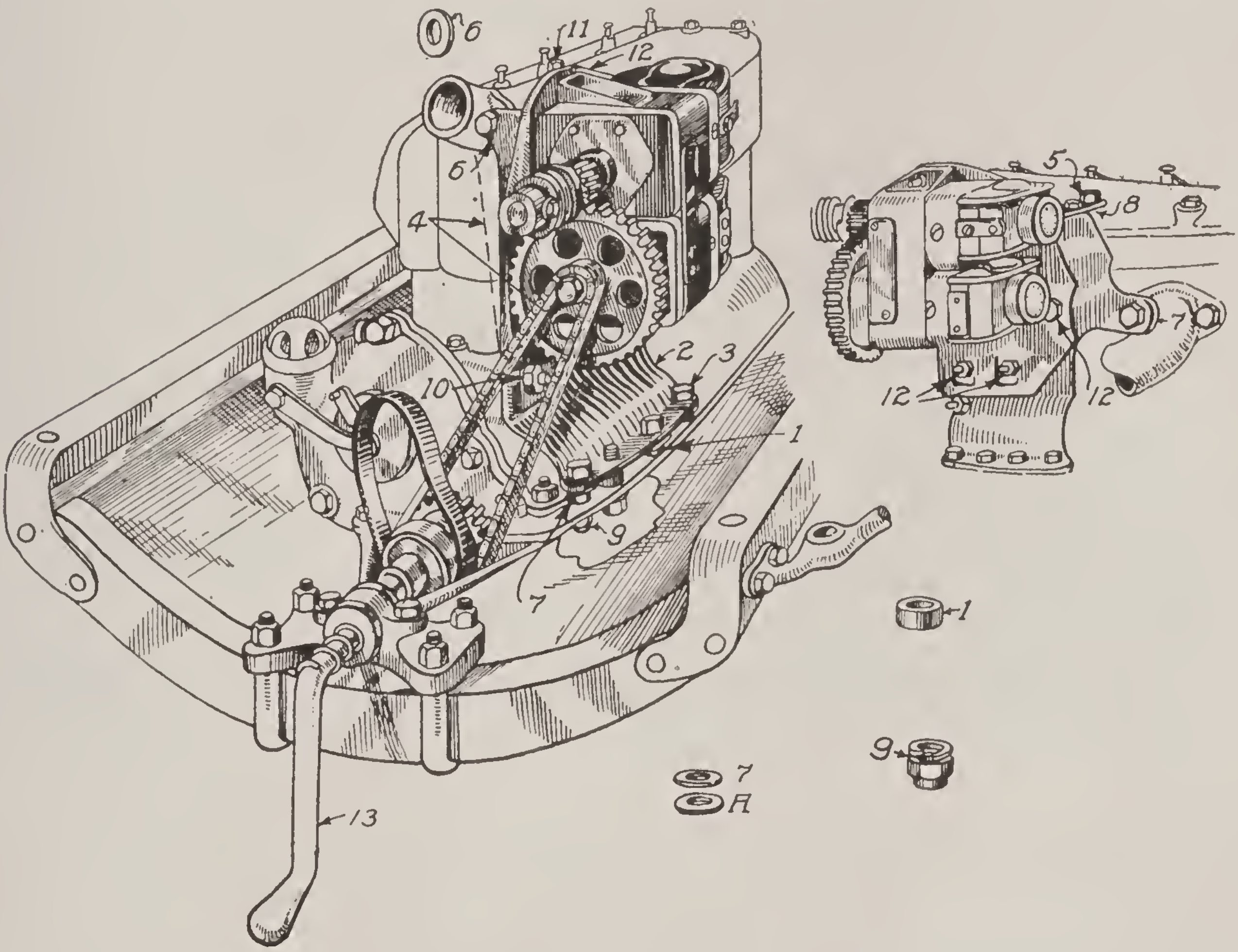


Fig. 386. Starter Unit Mounted on the Engine
Courtesy of Gray & Davis, Boston, Massachusetts

Place three $\frac{3}{8}$-inch spacers over the first, second, and third holes in the crankcase flange *1*, and then place the unit on car *2;* pass three $\frac{3}{8}$- by $2\frac{1}{8}$-inch bolts through the lower bracket, but do not attach nuts *3*. Tip the starter unit forward and pass the chain over the dynamo sprocket *4;* attach the bracket by meams of cylinder-head bolt, but do not fasten.

Place a $\frac{13}{32}$-inch spacer between the bracket and top water connection *7* and attach the bracket with $\frac{7}{16}$- by $2\frac{5}{8}$-inch bolts, but do not fasten securely; then place $\frac{1}{32}$-inch spacers *7A* under the bracket

so that the chain will be tight when the units are in the lowest possible position. Use washers *8* as shims between the bracket and the cylinder-head link. Secure the three lower bracket bolts *9* with lock washers and nuts, also secure the water-connection bolts *6* and *7* and the cylinder-head bolt *5*. Adjust the bracket stay bolt *10*, adjust the chain *11* to moderate the tension and lock adjustment, securely tighten five clamping bracket nuts, and then crank the engine slowly by hand to see that everything turns smoothly. If, through some irregularity in the engine casting the bracket should not seat properly, it may be necessary to file the bracket holes to meet this condition. Be sure that the sprockets are in true alignment, or the

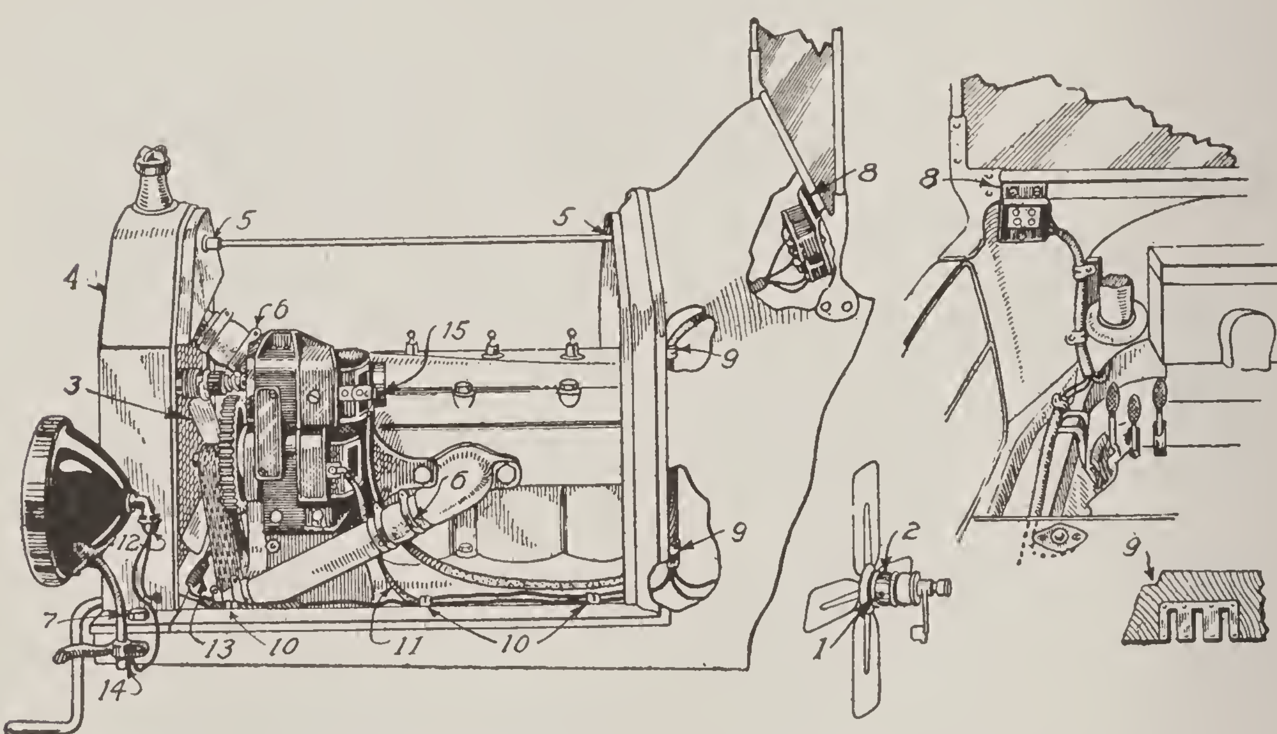


Fig. 387. Installing Gray & Davis Wiring and Lighting Switch on Ford Car

uneven strain may cause injury. If necessary, elongate the holes in the bracket or shim bracket as needed to insure perfect alignment of chain.

When adjusting the bracket stay bolt *10*, make sure that it rests against the engine casting without strain and secure it with nuts on each side of the bracket. Bend the ignition timing to clear the chain, if necessary, but after bending, the distance between the ends of the rod in a straight line must be equal to its original length. Adjust the chain to moderate tension and secure both the adjustment lock nuts at the top. If all five nuts holding the adjustable bracket are not released before adjusting, uneven strain may cause injury. Securely

tighten the sliding-bracket nuts *12*—two at the bottom front side, two at the top rear, and one at the front end. Test by turning the engine over by hand slowly.

Remounting Engine Parts. Fit split pulley *1* to the hub of the fan, Fig. 387, and attach split pulley *2* with four screws; slip a new belt over the fan pulley, attach the fan, and adjust. Place the radiator *4* on its support and screw the radiator rod into the radiator and secure with check nut *3;* secure the hose clamps at the top and side water connection *6;* place the radiator nuts and secure with cotter pins. Attach the lighting switch at the cowl (left) with $\frac{3}{16}$-inch screws and attach three lighting-cable clips on the rear of the dash, using $\frac{1}{2}$-inch wood screws; cut the corner from the toe board for clearance. Attach three wire clips *10* to the left side of the frame and attach green wire *11* to the dynamo terminal. Then connect [the short black and red wire to the left head lamp. Pass a long black and red wire through the radiator tube to the right head lamp, then connect the short wire from each head lamp to the metal of the car frame *14*. Attach the starting cable *15*, which has a copper terminal at each end, to the starting-motor terminal. Refill the radiator and watch carefully for leaks in the circulation system.

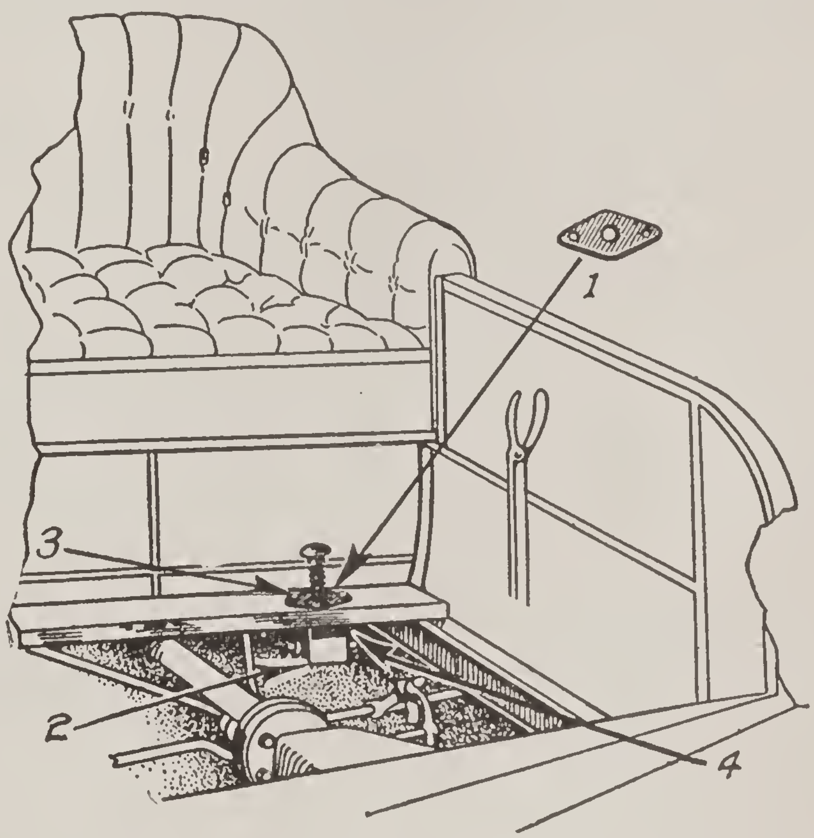


Fig. 3 8. Installation of Starting Switch
Courtesy of Gray & Davis, Boston, Massachusetts

Starting Switch. The location of the starting switch and the method of installing it are shown in Fig. 388. Take the plate *1* off the starting switch and use it to mark the holes in the floor strip two inches in front of heel board and nine inches from the sill, as shown in the illustration. Make three holes for the starting switch in the rear floor strip *2* and attach the switch with bolt *3* at the side nearest the center of the car; then attach the other switch bolt *4*, support

the cable clip holding the two wires, and secure the spring and the knob with a pin.

Priming Device. Connect the priming device *1*, Fig. 389. Drill a $\frac{7}{32}$-inch hole in the dash two inches to the right of the coil box and six inches above the toe board and pass the upper rod through. Connect the lever arm *2* vertically to the foremost exhaust manifold bolt with stationary member in horizontal position; then connect the lower rod *3* to the carburetor priming lever. Work it back and forth several times to make sure that it returns to normal position when released.

Battery. Place the battery box on the right-hand running board, Fig. 390, to permit easy opening of doors and access to battery box;

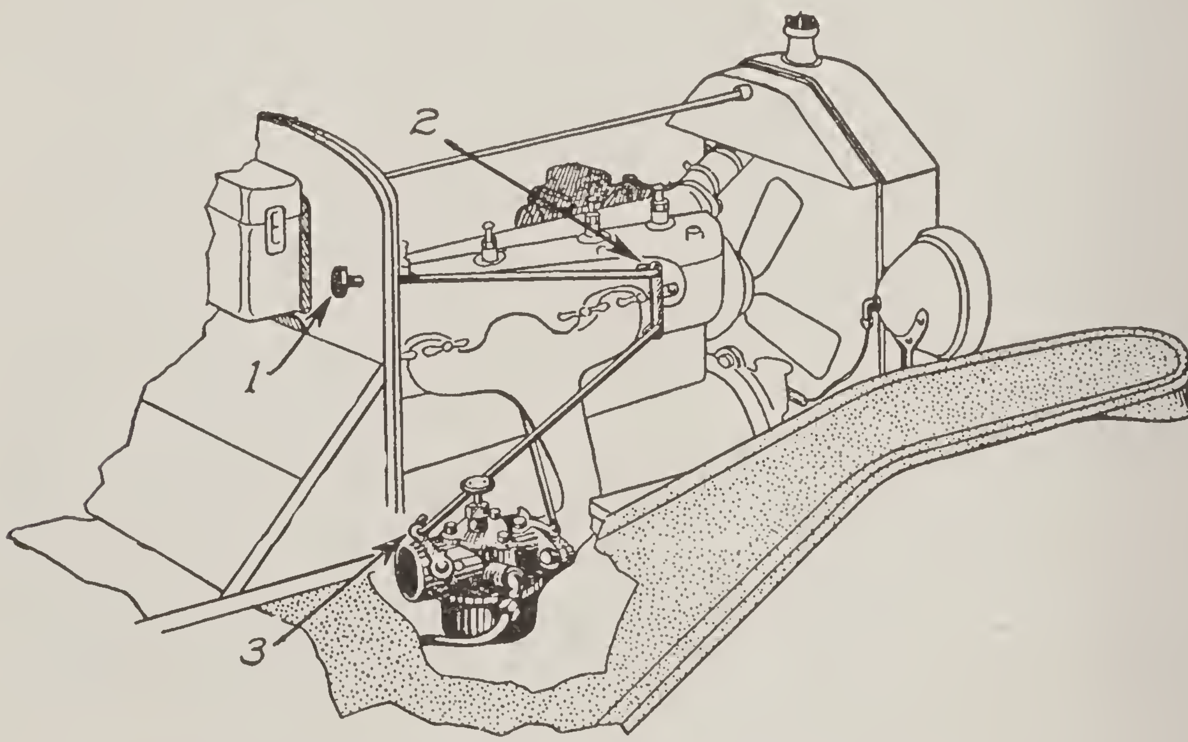


Fig. 389. Replacement of Carburetor Timing Rod on Dash
Courtesy of Gray & Davis, Boston, Massachusetts

then mark four holes with the center punch. Drill four holes $\frac{11}{32}$ inch in diameter in the running board *2*, using a jack or prop to support the running board while drilling. Replace the battery box on the running board in order to mark the holes in mud guard for insulating cable bushings *3*, then make two holes $1\frac{3}{8}$ inches in diameter. Insert insulating-cable bushing *4* in left hole and secure with round wooden nut; do the same with the right-hand bushing *5*. Secure wood nuts *6* with a wire twisted around the thread. A coat of heavy paint will also hold the nut in place and preserve the insulator. Place the two flat wood cleats *7* with holes at each end between the battery box and the running board; then pass four bolts *8*, $\frac{3}{8}$ inch by $1\frac{1}{2}$ inches, through

the battery box, cleats, and running board, and secure them with four nuts and lock washers. Place two special-shaped wood cleats *9* inside the battery box, one at each end for the battery to rest upon, so that holes in the cleats will fit over the bolt heads. Raise springs *10* and hang on the side of the battery box, placing the battery in the box and inserting two $\frac{1}{2}$-inch wood strips, one each side between the battery and the battery box. Attach two springs *11* at opposite ends

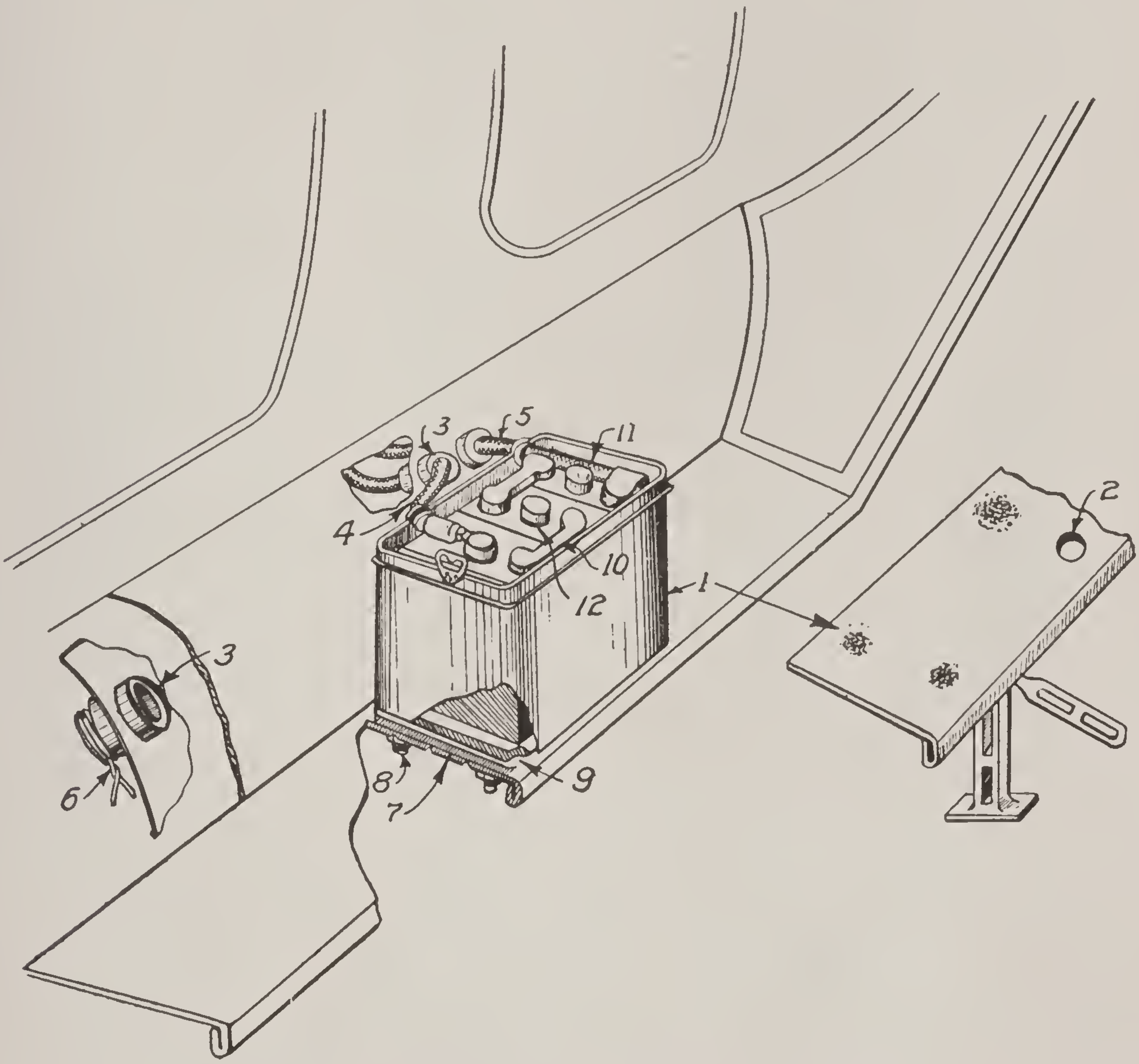


Fig. 390. Installing Gray & Davis Battery and Wiring

to hold the battery down securely. Inspect the battery and if the solution does not cover the plates at least $\frac{1}{4}$ inch, add pure water, filling the cells to $\frac{5}{8}$ inch above the tops of the plates. Water for battery use should be free from iron or alkali.

Final Connections and Adjustments. Fig. 391 is a plan view of the chassis, showing the entire system in place. Figs. 392 and 393 show the wiring in plan and in perspective. Drill and attach to the woodwork on the underside of the body *1* three wire clips holding the

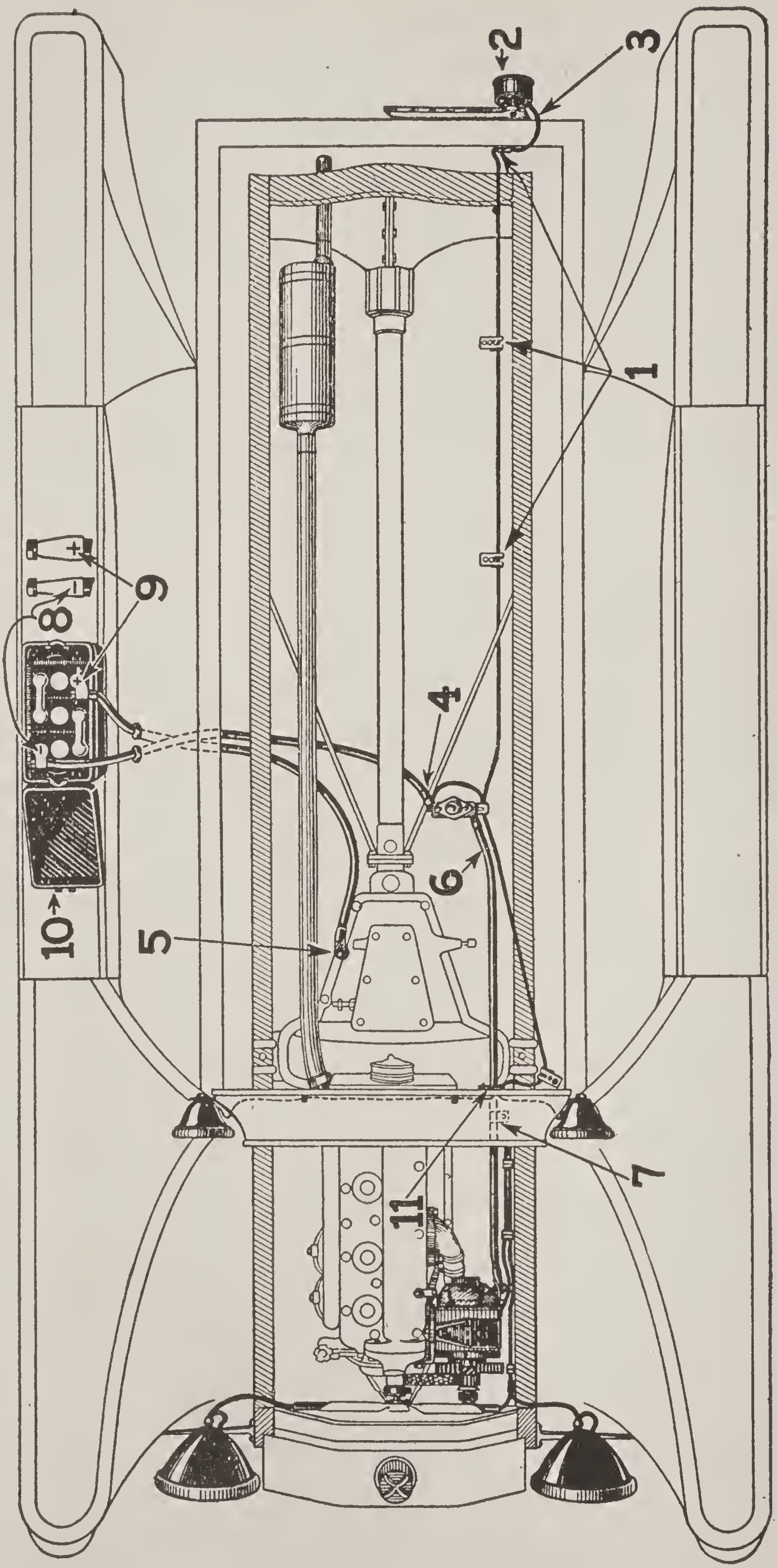


Fig. 391. Plan View of Complete Wiring System for Gray & Davis Ford Installation
Courtesy of Gray & Davis, Boston, Massachusetts

tail-light wire; see that the wire does not make contact with any metal edges. Attach the electric light *2*. If the tail lamp has a one-point wire connector, the lamp body must be metallically connected with

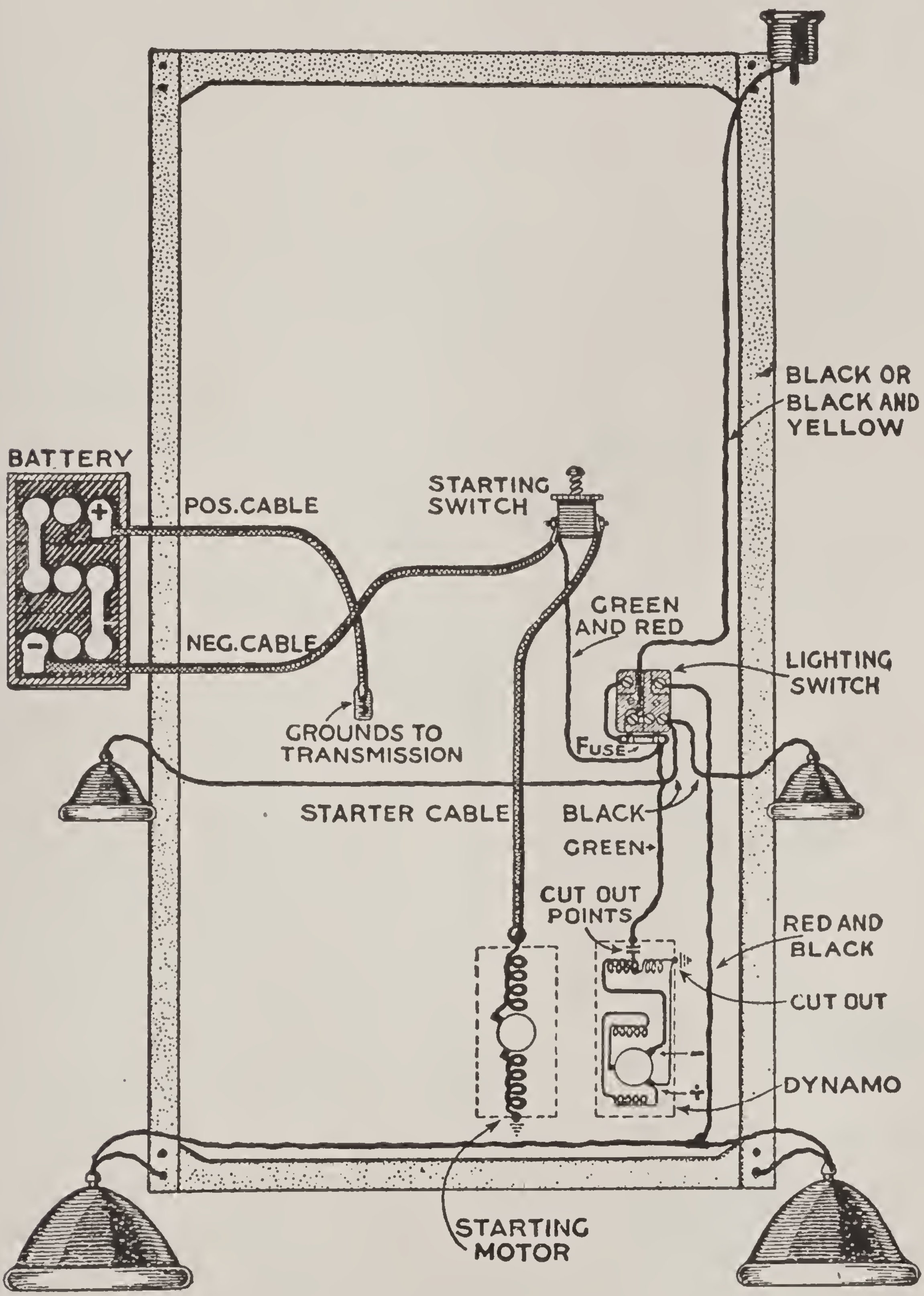


Fig. 392. View of Complete Wiring System Simplified

the chassis frame. Be sure the connecting surfaces are clean, free from paint, and securely connected. Connect the tail-light wire *3* to the tail lamp. Tail lamps are usually made with a single wire connector, but, if the lamp has two wire connectors, another wire

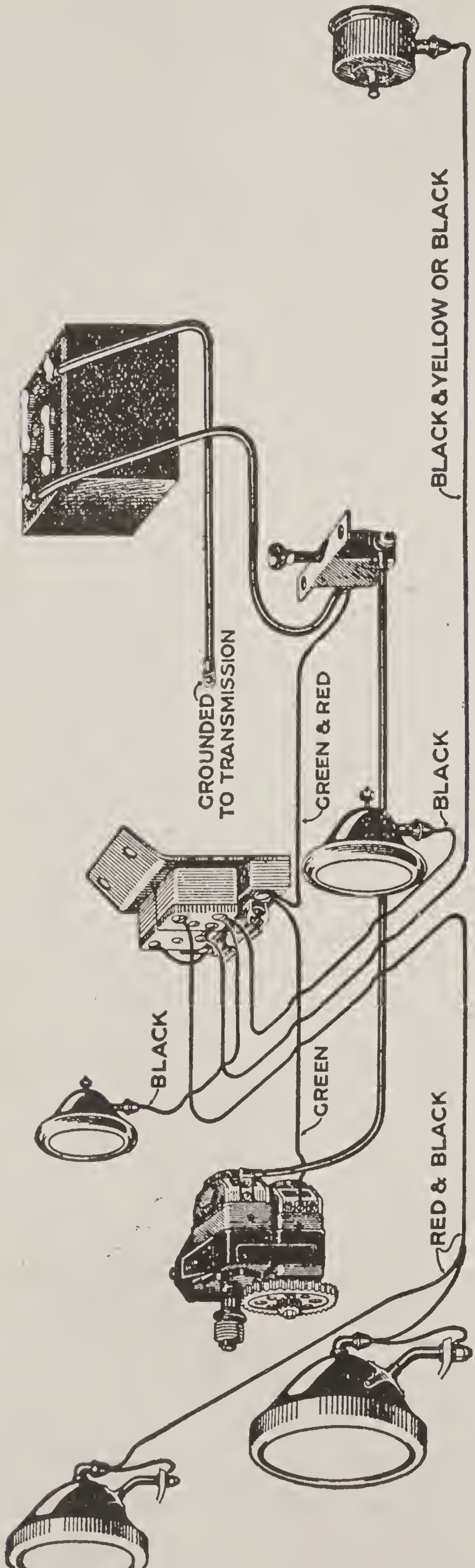


Fig. 393. Pictorial View of Wiring Diagram for Gray & Davis Ford Installation

should run from the second terminal of the connector to the metal framework of the car. Connect the short starting cable *4* (negative) and the green and red wire to the starting-switch terminal nearest the battery. Then pass the end of the battery cable through the foremost insulator in the mud guard. Attach the end of the starting cable *5*, leading through the rear hole in the mud guard, to the second bolt in the transmission case. Use a lock washer and a plain washer under the head of the bolt to insure permanent contact. Connect the long battery cable (positive) to the second transmission bolt and secure with a plain washer and a lock washer. Then pass the end of the cable through the rear insulator in the mud guard. Attach to the starting-switch terminal *6*, securely, the end of the cable which runs to the starter. Support the starter cable *7* by a clip to the inside curved edge of the dash. When connecting cables to the battery, be sure that the terminals are securely fastened—firm contact must be made. The battery terminals are made of lead and must be handled carefully. Battery-cable terminals

differ slightly in size and correspond to the holes in the battery terminal, the negative-cable terminal being the smaller. Pass the foremost cables *8* through the battery-box insulator and connect them firmly to the negative battery terminal. Do not connect the positive cable to the battery or insert the fuses until the installation has been made in accordance with the instructions and tests show that wires are not in contact with the frame of the car. Turn the lighting switch off and touch the positive terminal lightly to the battery terminal. If there is a spark, it indicates a short-circuit or a ground, caused by a wire coming in contact with the frame. Remedy the trouble before connecting up the battery. If there is no spark, permanent connection may be made. The lamp-test set may be used to determine whether there are any grounds or short-circuits, before connecting up the battery.

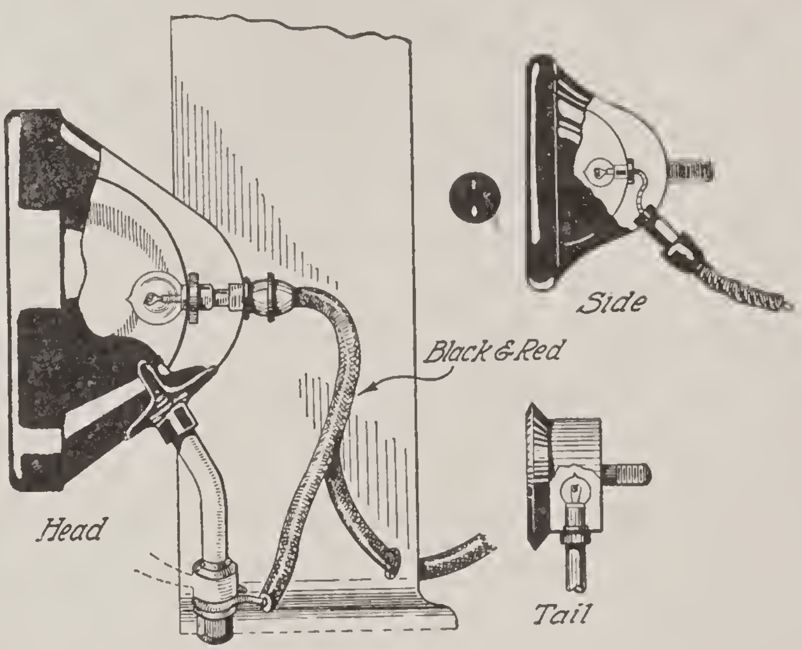


Fig. 394. Details of Gray & Davis Ford Lamps

When all indications show that the installation has been made properly, connect the positive starting cable to the positive terminal *9* of the battery. Place and secure the cover *10* on the battery box. Place fuse *11* in fuse clip of lighting switch. Fig. 394 shows details of the different types of lamps.

Instructions. Oil the two generator bearings and the two motor bearings every 200 miles, keeping oil-well covers closed The chain must be kept well adjusted. When the unit is first installed or when a new chain has been fitted, the chain should be adjusted occasionally during the first 500 miles of travel until all stretch has been taken out of it. After this distance has been run, the chain stretch will be slight. Never allow the chain to run slack.

To adjust the chain, release five clamping nuts (2 nuts in the rear of the bracket at the top, 2 in front of the bracket at the bottom, and 1 at the right-hand side) a few turns to permit the bracket to slide. Then adjust the chain to moderate tension by turning the adjusting

screw at the top of the bracket and tighten the check nut and adjusting screw to lock the adjustment. Then retighten all five clamping nuts securely. Turn the engine by hand to determine whether the chain runs smoothly; the chain should not be too tight. After long service, when all chain adjustment has been taken up, the chain may be shortened by taking out a pair of links. The latest type of chain is supplied with a removable pair of links, retained in position by two removable pins. These pins are a trifle longer than the regular riveted pins.

Where the chain has been shortened, it is sometimes necessary to lower the supporting bracket slightly by removing some of the $\frac{1}{32}$-inch washers under the bracket or by filing the spacers slightly, so that the chain will be tight when the unit is in the lowest possible position.

Wires are subject to dislodgement and injury, hence they should be examined carefully to see that they are not resting on sharp edges of metal and that the insulation is not worn or injured. See that none of the wires are swinging or rubbing against metal, as this is likely to injure the insulation. Also examine the cables leading through the battery box and mud guards; the bushings must be intact and in place to protect the cables from short-circuiting. Wherever injury to any part of the insulation is found, wrap the spot carefully with insulating tape and bend away from the metal to provide sufficient clearance to prevent further damage.

If the lamps fail to light when the lighting switch is operated, the fuse on the back of the lighting switch should be examined; it may be burned out, broken, or not properly clamped in its fuse clips. The wires may not be properly connected (this should be checked by wiring diagram), the bulbs may be burned out, or the filaments may be broken. The lamp wiring may be short-circuited or the charging circuit may be open.

Do not run the engine with the battery disconnected or off the car without first insulating or removing two of the generator brushes to prevent the generator from generating a current. To determine if generator is operating properly, turn on the head and tail lamps while the engine is idle. Start the engine and accelerate to charging speed or over; a perceptible brightening of the lamps will indicate that the machine is generating sufficient current both to charge the

battery and to light the lamps. Do not open the charging circuit at any time when the engine is running.

Testing Generator with Ammeter. A more accurate determination may be made by connecting an ammeter in the circuit. Disconnect the red and green wire connected to the fuse terminal on the back of the lighting switch and connect it to one terminal of the ammeter. From the other terminal of the ammeter, connect a wire to the fuse terminal to which the red and green wire was previously connected. Turn the lights on with the engine idle. The ammeter should register "discharge", the reading representing the amount consumed by the lamps turned on, i.e., head and tail lamps, 5 to 6 amperes; side and tail lamps, 1½ to 2 amperes. If the ammeter indicated "charge" instead of "discharge", with the lamps turned on and the engine idle, reverse the wires connected to the ammeter terminals. In case the ammeter does not register, see that the pointer is not jammed, otherwise, the circuit is open at some point or the battery is exhausted.

Run the engine at a speed corresponding to 12 to 15 miles per hour, the lights being turned off. If the ammeter registers "charge", the generator is then charging the battery. Increase the engine speed to a car speed corresponding to 13 to 18 miles per hour. The ammeter reading should then be from 12 to 15 amperes. As the engine speed is increased above 18 miles per hour, the charging rate will decrease gradually to approximately 10 amperes at very high speed. With the engine running at 12 miles an hour or faster, turn the lights on; the charging rate should drop according to the number and size of the lamps turned on (see current consumed by each lamp as given above). Turn the lights off and, while permitting the engine to slow down, observe the ammeter. It should drop to zero at approximately 0- to 2-ampere charge.

HEINZE-SPRINGFIELD

Preliminary Operations. Before beginning the installation, adjust the ignition and the carburetor so that the engine is working efficiently. Remove the radiator and the radiator tie rod; disconnect the water-inlet pipe from the side of the cylinder, but do not break the hose connection; also disconnect the water-outlet pipe from the upper forward end of the cylinder block. Remove the priming wire that protrudes through the front of the radiator and is connected to the

carburetor; disconnect the wires from the headlights, first removing the plugs from the sockets; and disconnect the wires from the connecting plugs. The radiator can now be lifted from the frame. After it has been removed, disconnect the water-outlet pipe from the hose and discard the latter. Remove and discard the ground-wire connection of the Ford lighting system, which will be found soldered to the lower left-hand corner of the back side of the radiator.

Remove the fan and the starting crank and the fan pulley. To take off the pulley, first remove the two cotter pins from the pin holding the fan pulley on the end of the crankshaft. Throw the speed lever in gear (allowing it to go forward to engage the clutch) and push the car forward or backward enough to turn the motor over so that the pin is in a vertical position, which will permit driving the pin down through the hole in the engine frame. Then remove the fan pulley and discard it with its starting pin and cotters.

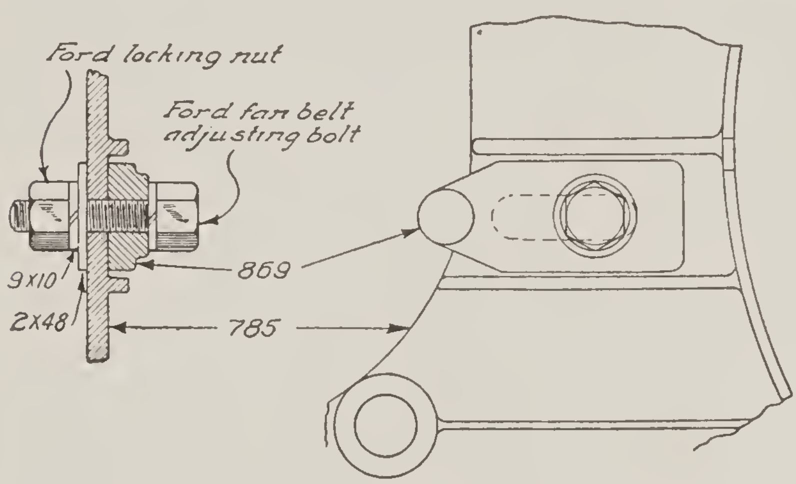


Fig. 395. Correct Assembly for Belt Tightener for Heinze-Springfield Ford Installation

Disconnect the advance rod from the timer case, placing the rod to the right to keep it out of the way of subsequent operations. Take out the cap screw running through the breather pipe. This will release the spring holding the timer housing in place, and the timer housing can be lifted off. Place it to the left, *but do not disconnect the wires.* Note carefully the position of the timer, or commutator-brush assembly, and then remove it from the camshaft by taking off the nut, the small steel brush cap, and the retaining pin holding the brush assembly to the shaft. *Do not turn the motor over while the timer brush assembly is off, and be sure to replace it in its original position when reassembling.* In this way the timing of the engine will not be deranged.

The timing gear, or cylinder front cover, should then be removed, retaining all the bolts, the nuts, the gaskets, and the cotter pins, for replacement in mounting the main-bracket plate 785 of the Heinze equipment, Figs. 395 and 396. It is necessary that the felt washers

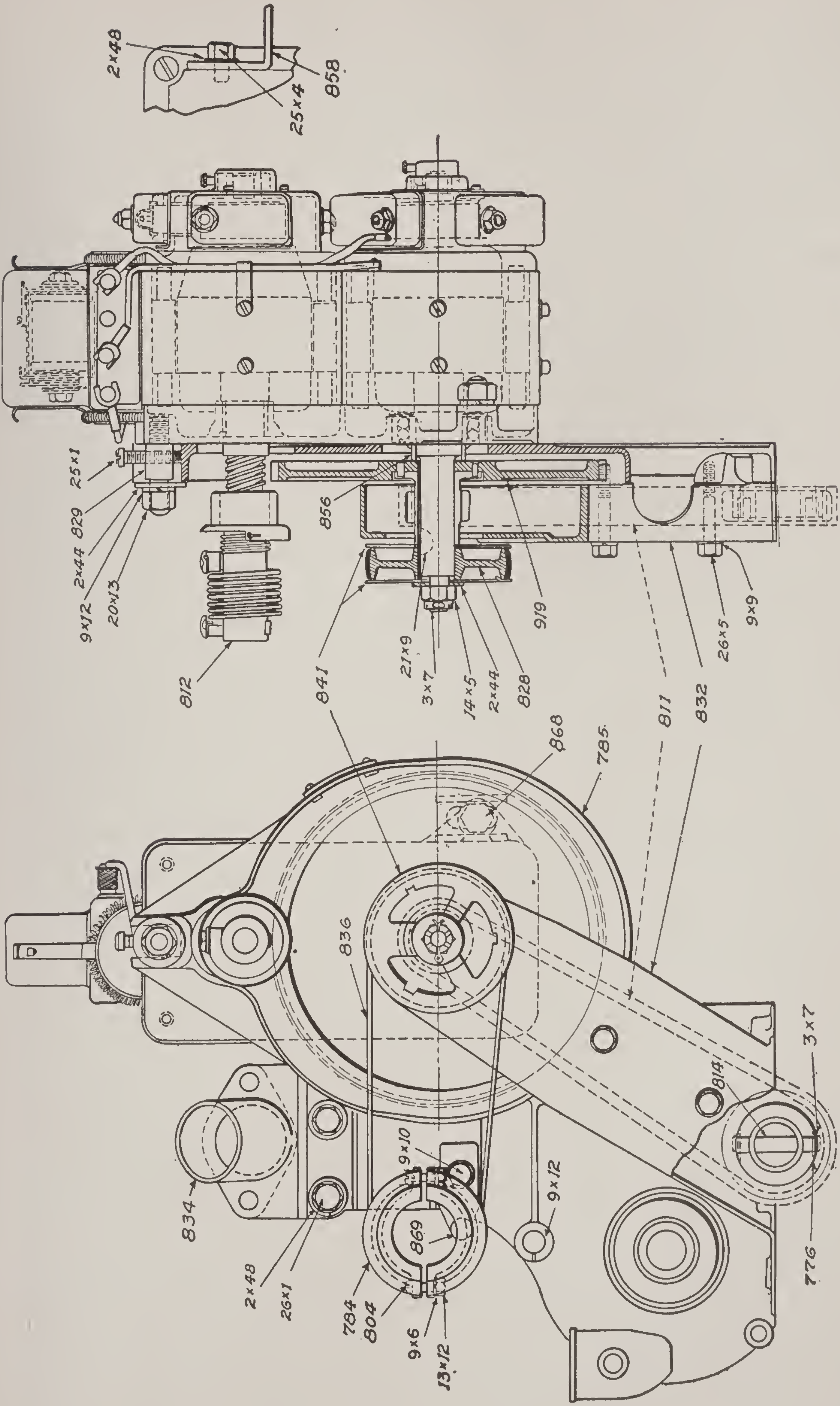


Fig. 396. Heinze-Springfield Starting Motor and Generator Unit Installed on Ford Engine
Courtesy of John O. Heinze Company, Springfield, Ohio

in this timing-gear cover around the crankshaft and the camshaft be removed and inserted in the corresponding positions on the new main bracket plate which takes the place of this cover. In case the car has seen considerable service and these felt washers are worn, it is advisable to replace them with new ones; otherwise, there will be a dangerous leakage of oil from the crankcase.

Secure the water-outlet header 834, Fig. 396, in place on the cylinder-head casting, using the original Ford bolts and gasket. Place the fan-belt tightener 865, Fig. 395, with the nose away from the large gear housing, in the slide provided for it on the main bracket plate 785. Remove the fan-adjusting screws and the locking nut from the Ford timing-gear housing plate and use them together with the two lock washers (9×10) and the plain washer (2×48), as shown in Fig. 395. Set the main bracket plate in position on the engine and bolt it securely in place, using the original paper gasket, the cap screws, the bolts, the nuts, and the cotter pin. Then bolt the main bracket plate 785 to the water-outlet header 834, using the two bolts (26×1), the lock washers (9×10), and the plain washers (2×48), Fig. 396. The commutator-brush assembly and the housing should now be replaced, taking care to put them in their original positions; then connect the spark-advance rod on the commutator housing.

Installing the Unit. *Generator-Motor.* The generator-motor unit should now be placed in position on the main bracket plate with the chain-adjusting stud 829 in place on the unit. This chain-adjusting stud should rest freely in the bottom of the slot at the top of the main bracket plate. Assemble on this chain-adjusting stud 829, the plain washer (2×44), the lock washer (9×12), and the nut (20×13). Place the lower adjusting bolt 868 in the slot provided for it on the main bracket plate. A lock washer (9×12) and a nut (20×13) are provided for this bolt. Place these in their respective positions, but do not tighten either the upper or the lower chain-adjusting bolts at this time.

With the unit loosely in place, proceed with the chain equipment as follows: Place the generator-shaft spacer 856 and the Woodruff key (21×9) on the generator shaft, Fig. 396. Place the gear and the sprocket assembly 919 also on the generator shaft, so that the large gear is on the inside toward the main bracket plate. Place the chain

811 around the sprocket 776 and also around the small sprocket on the generator shaft, taking particular care that the open side of the crankshaft sprocket is toward the front of the car. With the two sprockets and the chain in this position, slide the crankshaft sprocket 776 and the gear and the sprocket assembly 919 into place on the crankshaft and on the generator shaft, respectively, taking care that the starting-pin hole in both the crankshaft and the crankshaft sprocket 776 are in alignment. Insert the starting pin 814 with the counterbore of the cotter-pin holes toward the front of the car. These holes are also to line up with the two corresponding holes in the rear wall of the crankshaft sprocket 776. When the two cotter pins (3×7) are inserted, it is necessary that they be placed *clear through and bent over flat against the rear face of the crankshaft sprocket 776*. Unless secured in this manner, Fig. 397, there is great danger of the cotter pins breaking off and allowing the starting pin 814 to come out. *This will result in serious damage to the entire system.* By means of the fillister-head cap screw (25×1), Fig. 396, in the upper chain-adjusting stud 829, raise the generator-motor unit until the chain is reasonably tight. Then securely lock it in position by tightening the upper and the lower holding-stud nuts (20×13). The generator-motor unit and the driving-chain equipment are then securely installed.

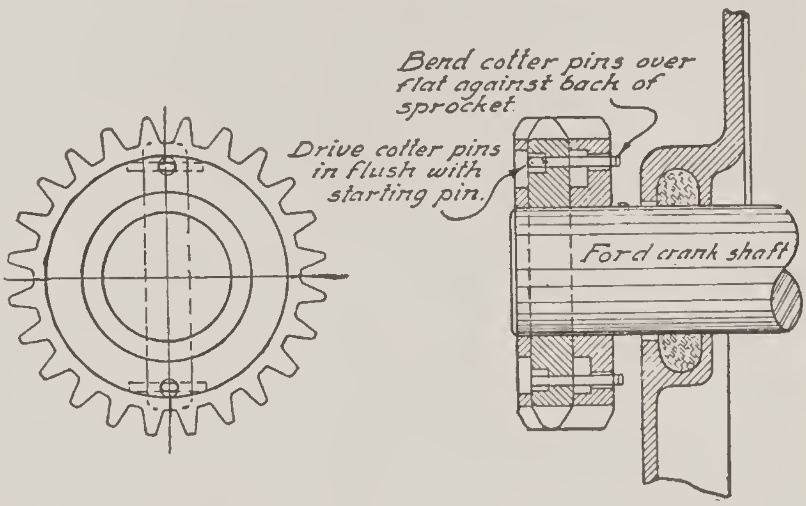


Fig. 397. Correct Heinze-Springfield Assembly of Crankshaft Sprocket

Chain Drive. The chain cover 832 is next to be placed in position, Fig. 396, using the cap screws (26×5) and the lock washers (9×9) to hold it securely to the main bracket plate. Place one of the fan-belt guards 841 on the generator shaft, with the three projections toward the front of the car. Then assemble the fan-belt pulley 828 against this guard and complete the fan-belt pulley assembly with the other fan-belt guard 841, this time, however, placing the three projections toward the rear of the car. These projections serve as centering points for the guards on the fan pulley, and the guards must

be assembled with the projections toward the pulley. This assembly should be locked securely to the generator shaft by the use of the plain washer (2×44) and the castellated nut (14×5). The cotter pin (3×7) must then be placed through the end of the shaft to lock this nut. Next install the motor rear-stiffening bracket 858 on the motor-brush head, using the bolt (25×4) and the washer (2×48) under the bolt head. Do not tighten this bolt until after drawing down the cylinder-head bolt securing the bracket to the engine.

Over the old Ford fan pulley assemble the two half pulleys 784, using the screws 804, the lock washers (9×6), and the nuts (13×12), Fig. 396. By this means, the fan belt runs closer to the fan blades than before. Now mount the fan in position on the main bracket plate 785, using the original Ford screw. Place the lock washer (9×12) between the Ford fan bracket and the main bracket plate, to lock the fan bracket securely in place. Adjust the new fan belt 836 over the two pulleys to the proper tension.

Bendix Drive. Next install the Bendix drive 812 on the starting-motor shaft, Fig. 396. Remove the drive bolt of the Bendix unit and place the latter on the shaft; then replace the drive through the hole in the end of the shaft and secure by means of the lock washer and the nut, taking care to bend the small projection on the special Bendix lock washer upward against the side of the nut.

Final Assembly. Before replacing the radiator, put back the hand crank and turn the engine over several times by hand to note that everything is properly installed and operates freely. Solder one end of each headlight ground wire to the inside face of the radiator, bringing the wires out through the holes provided for the headlight wiring, and be sure to allow sufficient wire to reach the head-light sockets. Then replace the radiator, using all the original bolts, nuts, gaskets, and cotter pins. It is advisable to turn the fan blades over slowly by hand before using the starting crank to make sure that the blades do not interfere with any part of the starting system or with the radiator. It is advisable to replace the hose connections of the radiator with new ones, and they must be tightened up very carefully to guard against leaks. When refilling the radiator, it should be noted whether there is the slightest sign of a leak and, if there is, it should be corrected at once, as any water falling on the starting system will injure it.

Switch and Wiring. Remove both the front and the rear floor boards from the car. About one inch to the right of where the steering post passes through the dash, there is a hole in the toe board, which was originally provided for the horn tube. Remove this board and enlarge the hole to the left about $1\frac{1}{2}$ inches, using this hole to bring the wiring through from the motor to the switch. Remove the Ford "magneto to coil" connection and also the "switch to terminal wire" connection and discard both of them. Also remove and discard all of the old headlight wiring. With the switch bracket in hand, see that the stay rod is screwed in flush with the face of the bracket. Next place the switch in the bracket so that the "off" position of the switch is on top, or nearest the switch-bracket flange. Fasten the switch securely to the switch bracket by means of four flat-headed screws.

Take the complete wiring assembly as received, enclosed in the 13-inch length of the circular loom, and, with the switch mounted in the switch bracket, connect the wires, being careful to assemble the proper terminals on the proper binding posts, Fig. 398, as follows: one large wire with the terminal *SM* on the post *SM;* one large wire and one small wire *SB* on the post *SB*. There then remain three small wires with the terminals *C*, *M*, and *L*, which are to be placed under the heads of the spring-terminal posts bearing the corresponding letters. The spring terminal *AM* is for the ammeter only.

Assemble the switch and the bracket on the dash. By use of the two switch-bracket clamps, the fillister-head screws, and the lock washers, fasten the switch bracket to the dash, slightly to the left of the steering post, in such a position that the hole in the end of the stay rod will line up with the Ford body bolt. Remove the nut from this bolt and clamp the stay rod securely. The foregoing instructions refer to the Ford touring car, the runabout, and the coupelet models.

In the case of the sedan model, by the use of three round-head blued wood screws, fasten the switch bracket to the dash, slightly to the left of the steering post, in such a position that the hole in the end of the stay rod will line up with the Ford body bolt. Remove the nut from this bolt and clamp the stay rod securely. This is a special stay rod 943 and is supplied only for the sedan model, so that the latter must be specified in ordering.

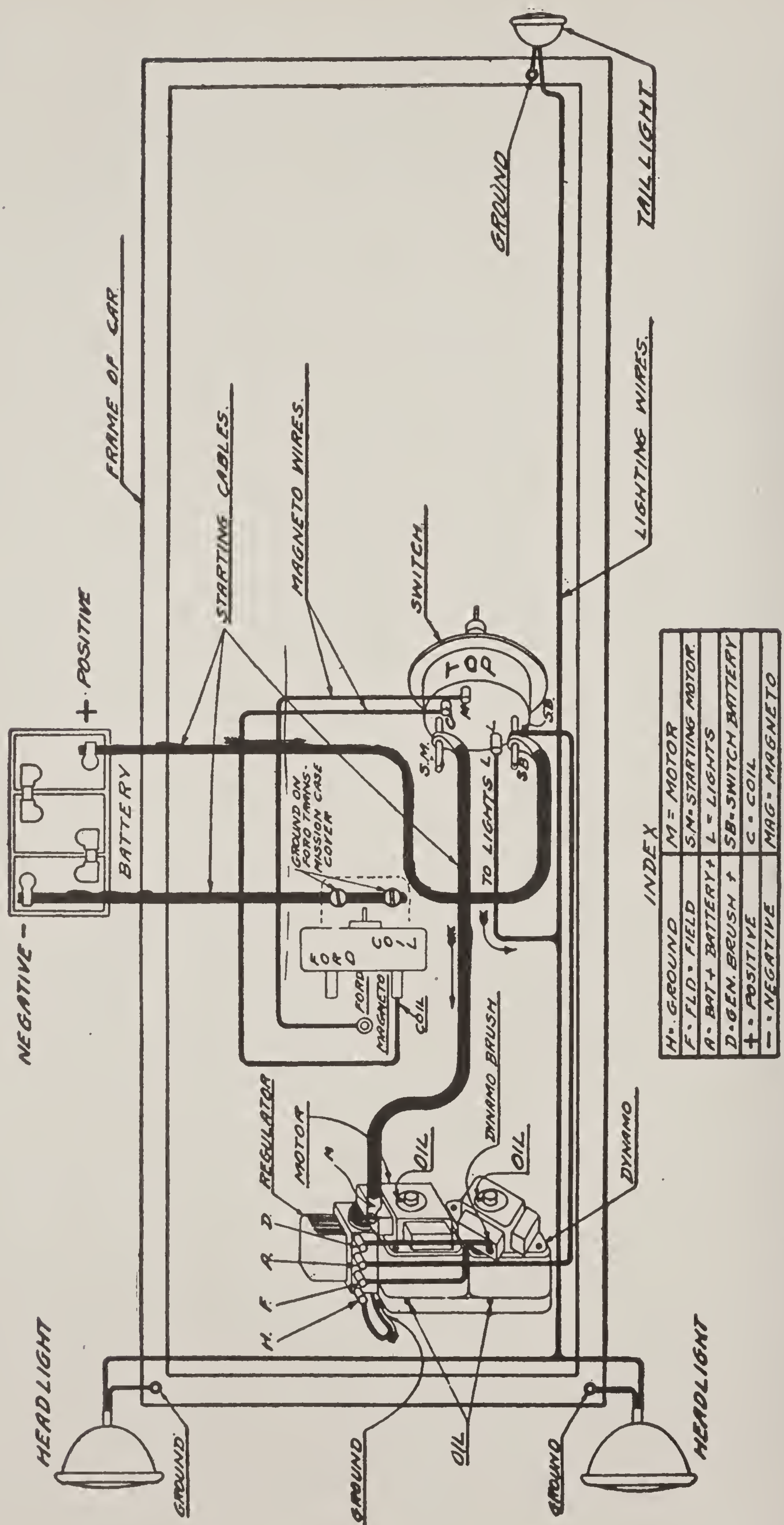


Fig. 398. Wiring Diagram of Heinze-Springfield Ford System without Ammeter or Dash Lamp

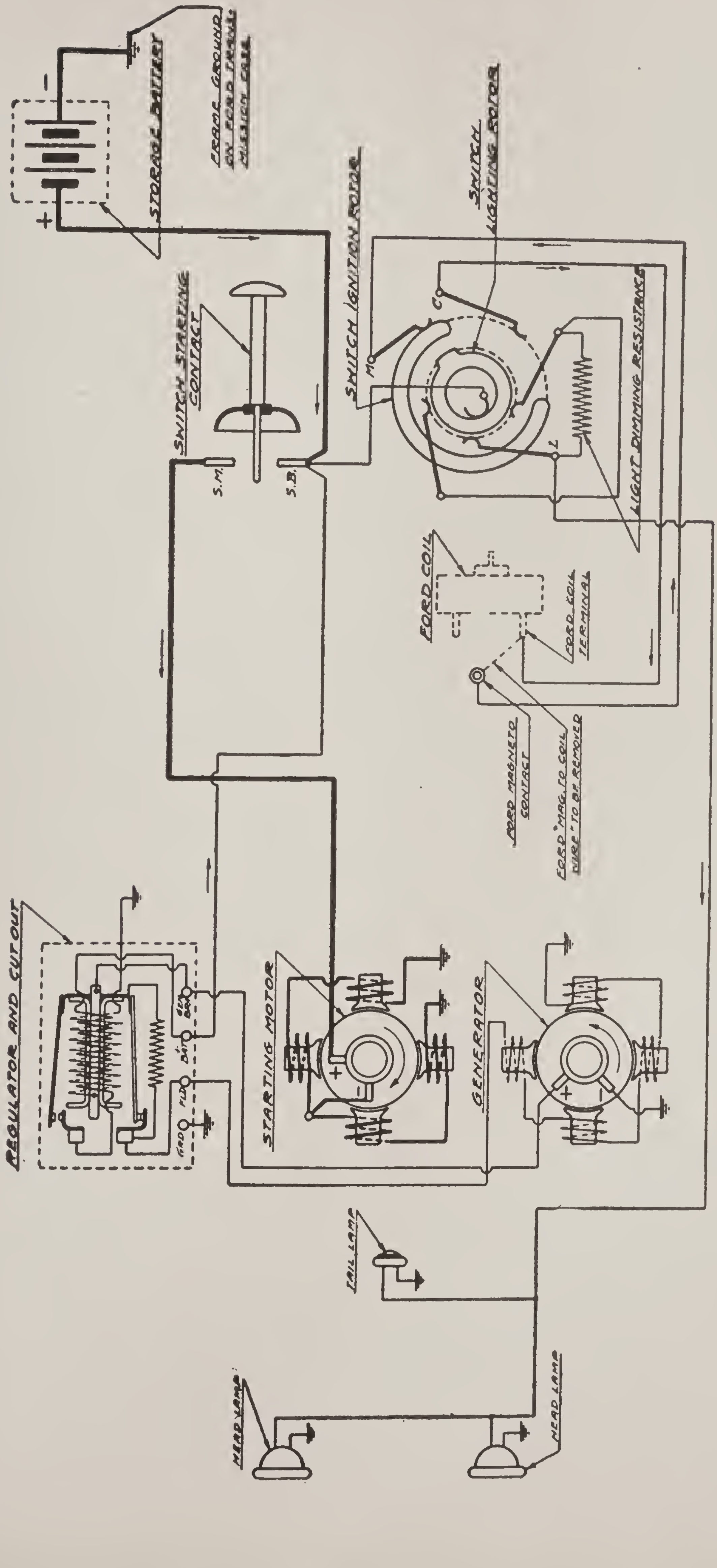


Fig. 399. Wiring Circuit of Heinze-Springfield Ford System without Ammeter or Dash Lamp

Coil and Magneto Wiring. Extending through the 13-inch length of the circular loom are two wires, one end of each being connected to the spring terminals *C* and *M* on the back of the switch, Fig. 398. Connect the wire from the terminal *C* to the magneto terminal on the rear of the Ford coil box; connect the wire from the terminal *M* to the magneto contact on the flywheel housing. These two terminals were formerly connected by the Ford "magneto to coil wire", which has been discarded, Fig. 399.

Charging Wire and Starting Cable. On the back of the switch on the post *SB* are connected one large and one small wire, Fig. 398. The small wire is to be connected to the terminal on the regulator *A*. On the back of the switch on the post *SM* is connected the "switch to starting motor" cable, on the other end of which the terminal *M* is to be connected to the upper, or positive, starting-motor brush.

Wiring for Lights. On the back of the switch on the spring terminal post *L* is connected a lighting cable, which is to be connected to the headlights and the tail light, Fig. 398. Three wires are provided which are to be used to ground one side of each light. To ground the tail light, run the ground wire under the tail-light frame bolt. If an oil lamp is used, tape the end of the light wire which is provided for an electric tail light and secure it to the tail-light bracket, so that if the electric light is subsequently installed, the wiring will be there for it. Secure the lighting cable to the car frame at several convenient points to keep it free from oil and to prevent chafing, which would cause grounding of the lighting circuit. When single-contact lamps are used, ground wires are not necessary, as one side of the lamp socket itself is grounded.

Battery Cables. Before connecting the positive (+) battery terminal to the switch terminal and the negative (−) battery terminal to the ground cable, be sure that the switch is in the "off" position. Then connect these wires as follows: Under the front floor board is the Ford transmission-case cover which is held in place by six bolts. Remove the upper right-hand bolt and assemble under this the starting-cable clamp. From the post *SB* on the back of the switch, Fig. 398, run the positive battery to the switch cable, placing it under the starting-cable clamp. Pass this cable through the circular loom placed between the running-board apron and the bottom of the body,

and through the hole in the battery box to the positive terminal of the storage battery.

Remove the two lowest bolts on the transmission-case cover and clean the transmission-case cover with a piece of sandpaper or emery cloth to insure a good electrical contact at this point. Under these bolt heads, assemble the brass ground strip on one end of the negative of the battery to the ground cable and run the other end through the circular loom mentioned above, then through the hole in the battery box to the negative terminal of the storage battery. Tighten these wires securely to the storage-battery terminals, using pliers for this purpose.

Installing the Battery. On all the different types of Ford cars, the battery is placed on the right-hand running board, midway between the front and the rear fenders, particular notice being taken that the battery box does not interfere with opening the door. In the bottom of the battery box are six holes, the four inside holes being provided for the four carriage bolts holding the battery box on the running board, and the two outside holes being provided for the two battery hold-down rods which hold the storage battery securely in place. Six corresponding holes $\frac{5}{16}$ inch in diameter must be drilled in the running board, to correspond to the six holes in the bottom of the battery box. Two wood pads are provided, which are to be placed inside the battery box. Two steel reinforcing pads are also provided, which are to be used under the running board. Place the four carriage bolts down through the wood pads, the battery box, the running board, and the steel pads, and clamp by means of carriage-bolt nuts. Next place the storage battery in the battery box with the positive (+) terminal toward a rear of the car, and by means of the hold-down rods which are hooked over the handles of the storage battery, fasten securely, using lock washers and nuts.

At a point midway between the two wire holes in the battery box, pry down a part of the running-board apron with a large screwdriver or a pinch bar, providing sufficient space between the running-board apron and the bottom of the body for the four-inch length of the circular loom through which the two battery cables pass.

Choker, or Priming-Rod, Assembly. On the air-gate lever of the carburetor, connect one end of the choker cord under the outside bolt which connects the carburetor and the inlet pipe, assemble

the choker loop in a vertical position, and pass the choker cord through the upper loop. On the dash, to the left of the carburetor adjustment, drill a $\frac{1}{4}$-inch hole. Through this hole pass the other end of the choker cord and connect the choker ring. This choker assembly displaces the Ford choker wire (carburetor-priming device), which extends through the radiator before the starting system has been installed. It is used to shut the air supply from the carburetor, so as to increase the suction through the carburetor nozzle and facilitate starting.

Tail and Side Lights, Horn, Etc. The use of an electric tail lamp is not necessary to the operation of the system. Provision has been made for an electric tail lamp, which is not furnished with the equipment, but, owing to the small additional cost and its great convenience, its use is advised. It should be wired as shown in the wiring diagrams, Figs. 398 and 400. If a single-contact tail lamp is used, it is not necessary to employ the ground wire, as one side of the lamp socket is already grounded to the car frame. In as much as there is emobdied in the lighting system a light-dimming resistance for the headlights, which is governed by the combination switch, it is not advisable to convert the oil side lamps to electric. The horn supplied on the Ford (No. 196 and later models) car is operated by the alternating current from the magneto. This horn may be used without interfering with the starting system, but cannot be operated by the storage battery. If desired, a direct-current horn may be installed and should be connected as shown in Figs. 400 and 401.

Ammeter and Dash Lamp. These are not furnished with the system as described, but may be had at an additional cost. This equipment consists of a switch bracket and an ammeter reading to 30 amperes, charge and discharge; a single-contact dash lamp with a self-contained switch and all the necessary wiring. In order to connect the ammeter in the charging circuit, there must be a spring binding post on the back of the combination switch *AM*, Fig. 400. All of the later combination switches of this make are fitted with this binding post. On the back of the combination switch, from the spring binding post *AM* to the round-head screw, there is connected a small flat brass strip. Break this strip connection by cutting in the center, using the pliers or a hack saw. Connect the ammeter and the dash lamp in the circuit, as shown, being very careful to connect the wire

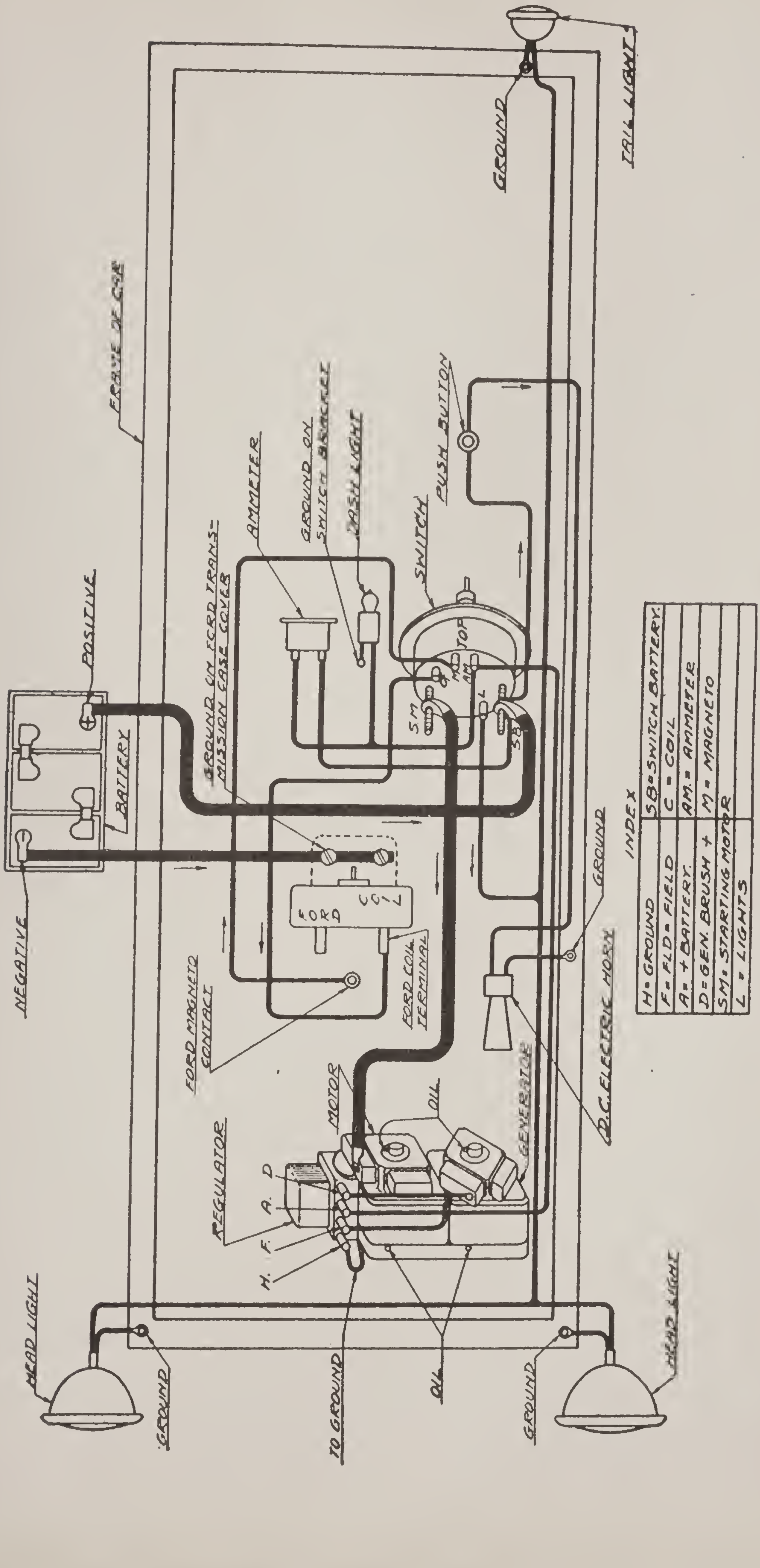


Fig. 400. Wiring Diagram of Heinze-Springfield Ford System with Ammeter and Dash Lamp

from the post *SB* to the "discharge" side of the ammeter and the wire from the spring binding post *AM* to the "charge" side of the ammeter. One end of the charging wire, running from the battery positive terminal of the regulator and the cut-out to the terminal *SB* on the back of the switch, must be changed over from the terminal *SB* to the binding post *AM*, Figs. 398 and 400.

Testing and Operation. Place the brake lever, the spark, and the throttle levers in the usual starting position, then unlock and rotate the combination switch lever to any of the three positions desired, as follows: "lights off, ignition on"; "lights dim, ignition on"; "lights bright, ignition on". Depress the starting button in the center of the combination switch. This sends the current from the storage battery through the starting motor, and the rotation of the starting motor causes the small gear on the Bendix shaft to mesh with the gear on the generator shaft. Riveted to this gear is the sprocket over which the silent chain runs. During the interval that the starting motor is in operation, a heavy current is drawn from the storage battery, and, if the lights are on, there will be a perceptible dimming caused by the decrease in the battery voltage. This is especially noticeable when the battery is nearly discharged, and will also be more apparent when the engine is stiff and hard to crank, or when there is a loose connection in the battery circuit. Although a fully charged battery is capable of cranking the engine for several minutes, it is not advisable to continue cranking longer than a few seconds, owing to the heavy discharge. If the engine does not start in this time, the choking device should be used to prime the carburetor. Should this not start the engine, investigate the cause before cranking further, as otherwise the battery will be exhausted. Frequent discharging of the battery in this way shortens its life. The front and the rear bearings of the starting motor should be oiled every 500 miles, though the Bendix drive-screw shaft should never be oiled nor lubricated in any way. The screw gear works to the best advantage when the shaft is dry.

As the mounting bracket is bolted to the machined surface of the timing-gear housing of the engine, the silent chain must be kept in good alignment at all times, and it must also be kept sufficiently tight to prevent it from striking the chain guard as well as to avoid the possibility of the chain teeth riding the sprocket, in which

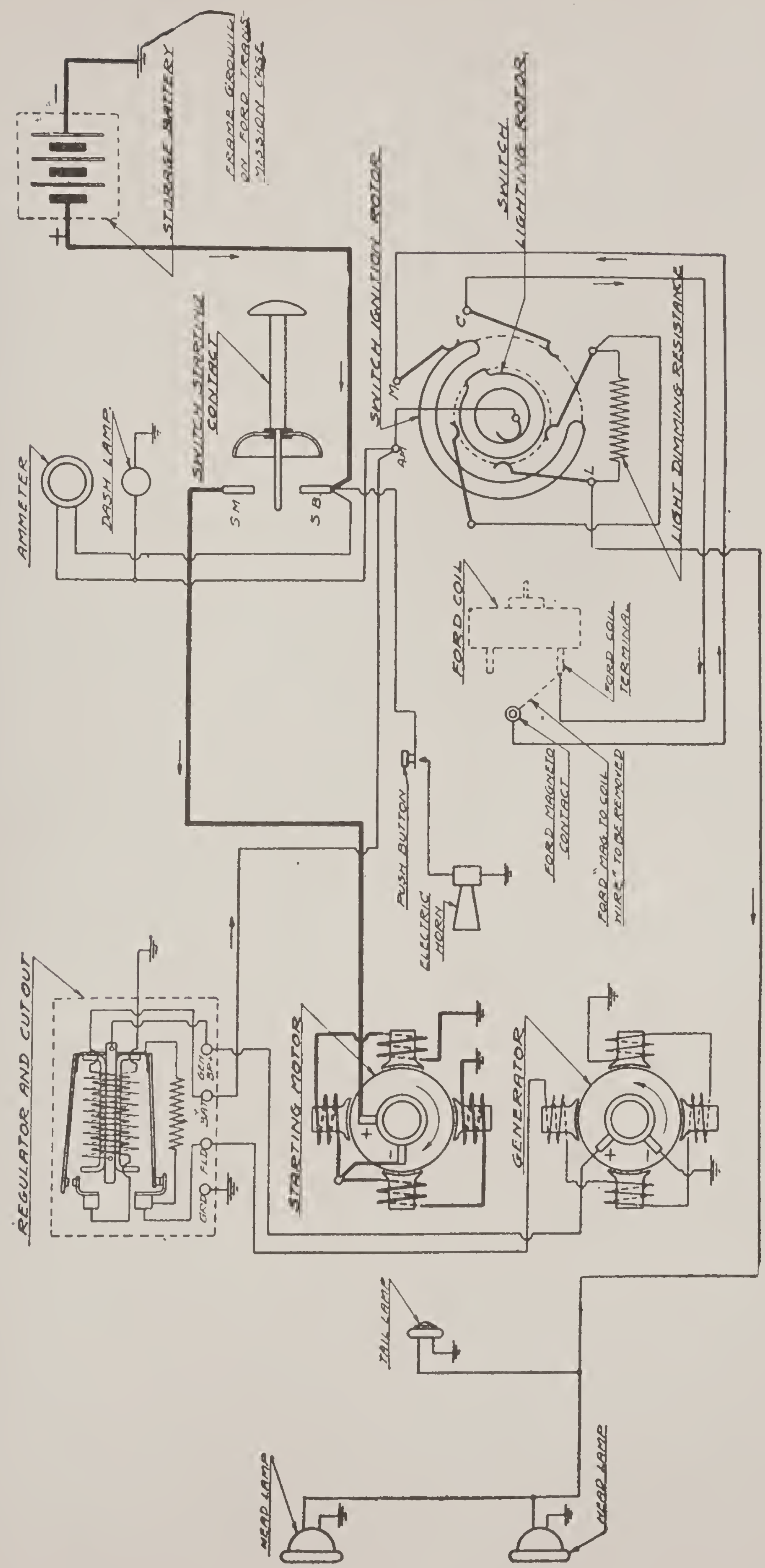


Fig. 401. Wiring Circuits of Heinze-Springfield Ford System with Ammeter and Dash Lamp

case the chain will break because of the severe strain placed upon it. The battery cut-out is designed to close when the car is traveling about 6 miles per hour, at which speed the charging current is about 4 amperes, increasing rapidly to 10 to 12 amperes at 10 miles per hour. After the car has been run the first hundred miles with the starting system in operation, the chain should be adjusted to take up the slack caused by the stretch; after that it should be inspected about every 300 miles. The operation of the regulator and the care of the system is given in detail in connection with the general descriptions, in alphabetical order.

FISHER

Preparing Engine. This is a twelve-volt two-unit type, the two members of which, for convenience in mounting, are combined as a

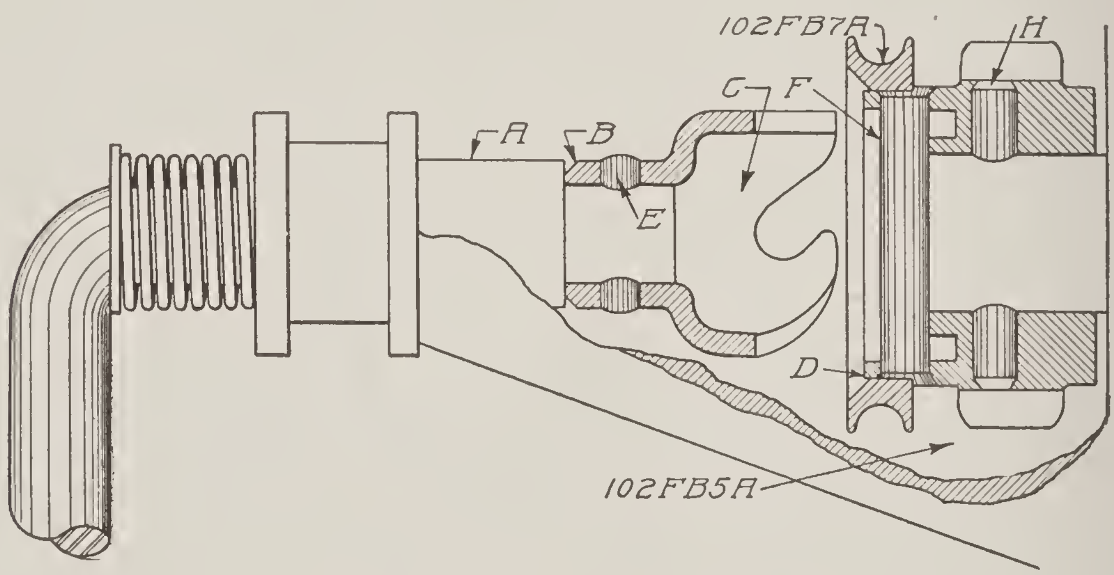


Fig. 402. Crankshaft Pin and Sprocket on Fisher Ford Installation

single mechanical unit. To install, the radiator, the water connections, the fan, the starting crank, and the fan pulley on the crankshaft must be removed. The lower water connection, or elbow, at the side of the cylinder block need not be taken off, but must be loosened. Place the new sprocket 102FB5A, Fig. 402, on the end of the crankshaft, driving the pin *H* through the cross-hole in the end of the crankshaft, burring the pin slightly so that it cannot drop out. This secures the sprocket to the engine crankshaft. The pin *F* is placed in the sprocket before shipment.

Then slip the pulley 102FB7A over the end of the sprocket up to the shoulder. Secure the pulley by several center punch marks between the end of the sprocket and the internal diameter of the pulley at *D*. If it is desired to retain the Ford starting crank in place

(this is preferable to carrying it in the tool box), cut $\frac{3}{16}$ inch off the crank ratchet *C*, Fig. 402, at the shoulder *B*—the original hole in the crank ratchet *C* and the starting crank are not disturbed. If there are burrs on the crank ratchet or if it is too large to enter the chain sprocket, the tips must be filed off or turned down in a lathe.

Mounting the Starting Unit. Remove the right-hand bolt of the top water connection 102FB16, Fig. 403, and the second bolt on top of the cylinder 102FB12. If there are rough places on the casting under these bolts, they must be removed. Take from the starting unit bracket 102FB3 and place the bracket in the position shown in Fig. 403. Between the bracket 102FB3 and the water connection is placed a heavy steel spacing washer. The bracket must be bolted securely in place against the water connection by the bolt 102FB12. The careful placing of the bracket and the clamping of these bolts is essential to the successful operation of the installation. After the bolts mentioned are securely in place, turn the set screw 102FB10 until it rests securely and firmly on the engine casting and, when it is firmly bedded, lock it securely by screwing home the lock nut. The purpose of this set screw is to take care of the stresses between the shaft of the generator and the crankshaft of the engine; note that the end of the screw must rest on the casting, otherwise the driving chain may be injured.

Place the starting unit 102S1A on the bracket and clamp it in its lowest position with the nuts on the studs. A long-shank **T**-wrench is the handiest to use for this work. The chain, which is coupled with a bolt and a cotter pin, may now be put in position. Roll the chain under the sprocket 102FB5B and on the sprocket 102FB13 on the electric unit. Bring the links together and slip the bolt through toward the radiator and put the washer and the cotter pin in place. Tighten the chain by loosening the nuts, Fig. 403, holding the starter to the bracket and the nuts 102FB18, then turning the set screws 102FB11 up until the chain feels taut when pressed with the fingers. Tighten the bracket nuts and the lock nuts 102FB18. Turn the engine over a few times with the starter and tighten the chain again. This should be repeated after the car has been in use a few days. The life and the service of the chain will be greatly increased by keeping the proper tension on it, particularly during the first few days it is in use, when it is stretching.

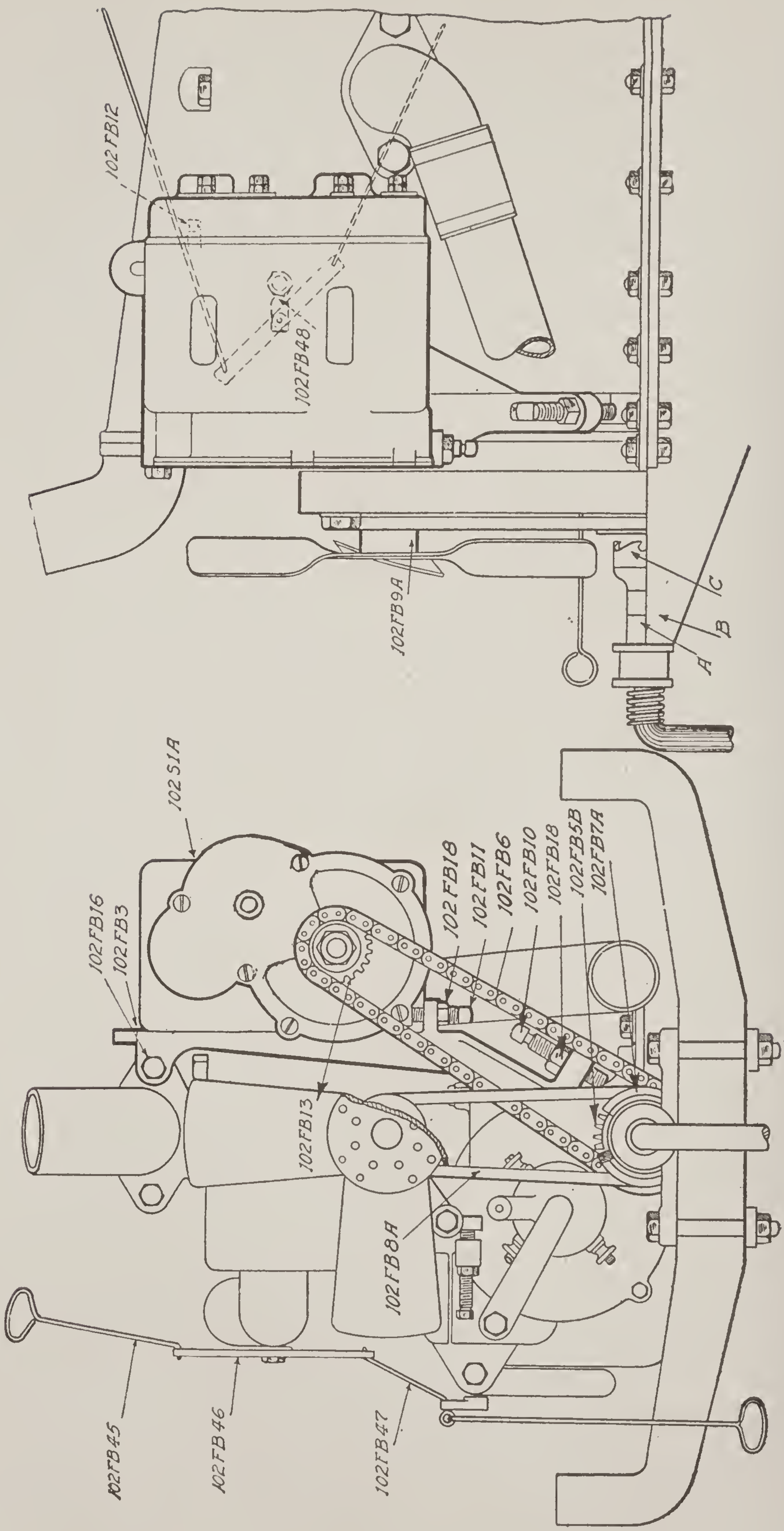


Fig. 403. Front and Side Elevators of Fisher Ford Starter

Separate the split pulley 102FB9, Fig. 404, and the clamp on the shaft of the fan between the brass pulley and the fan blades by the two screws. The diameter of the bore of this pulley is slightly less than that of the neck of the fan so that it may be filed down with a round file to fit the neck of the fan pulley. When this pulley is in position, hook the round belt 102FB8A, Fig. 403, furnished with the equipment, over the pulley on the crankshaft and the pulley on the fan.

Remove the plug from the top of the electric unit and, with the aid of a grease gun, squirt one-half pint of good transmission grease into the gear case of the unit, and then replace the plug. This will lubricate the gears for a period of six months.

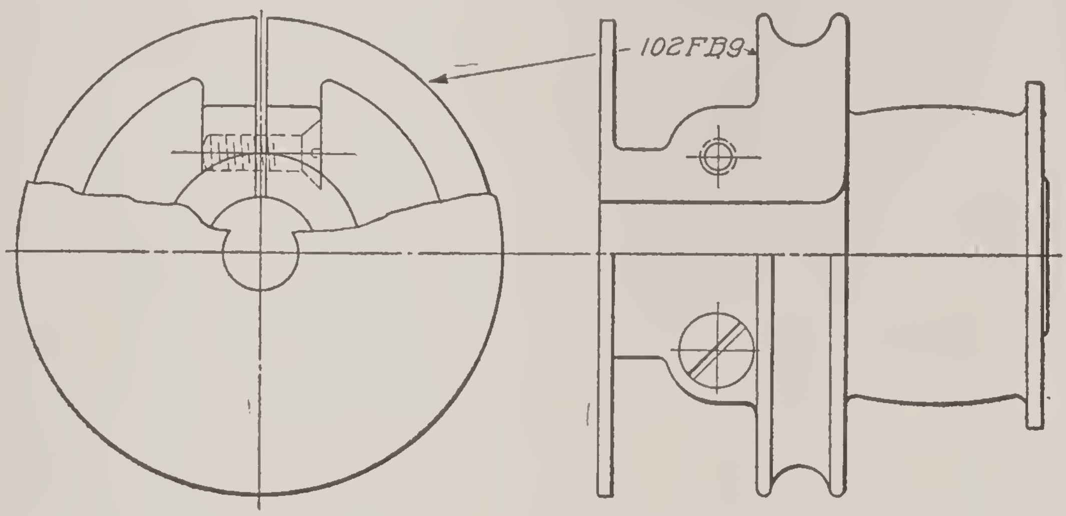


Fig. 404. Part Section of Fisher Split Pulley

Battery and Wiring. The battery box may be located on either running board as convenience dictates, holes being drilled in the apron to pass the battery cables. Place short pieces of $\frac{1}{2}$-inch "flexduct", or circular loom, in the wiring holes through the battery box and the metal apron of the car and the 1-inch flexduct between the transmission cover and the engine hanger on the left and let it extend back past the brake pedals. Place the instrument board carrying the ammeter, the lighting switch, the starting switch, and the dash lamp, under the cowl dash to the left of the steering column. The length of the wires necessary to connect the battery to the various essentials can now be measured to suit this particular installation.

Run the large negative starter cable from the negative (−) post of the battery through the flexduct insulation in the battery box and by the transmission case to the negative post on the motor. From

the positive terminal of the battery, run a cable through the flexduct insulation to the binding post of the starting switch, as shown in Fig. 405; from the other binding post run a cable to the positive brush holder of the motor. The terminals on these cables should be soldered, and the binding posts tightened with a wrench. (Whenever soldering has to be done on electric wires, use a noncorrosive flux and *not an acid,* as the latter not only is an electrical conductor but will also corrode the joint surfaces.)

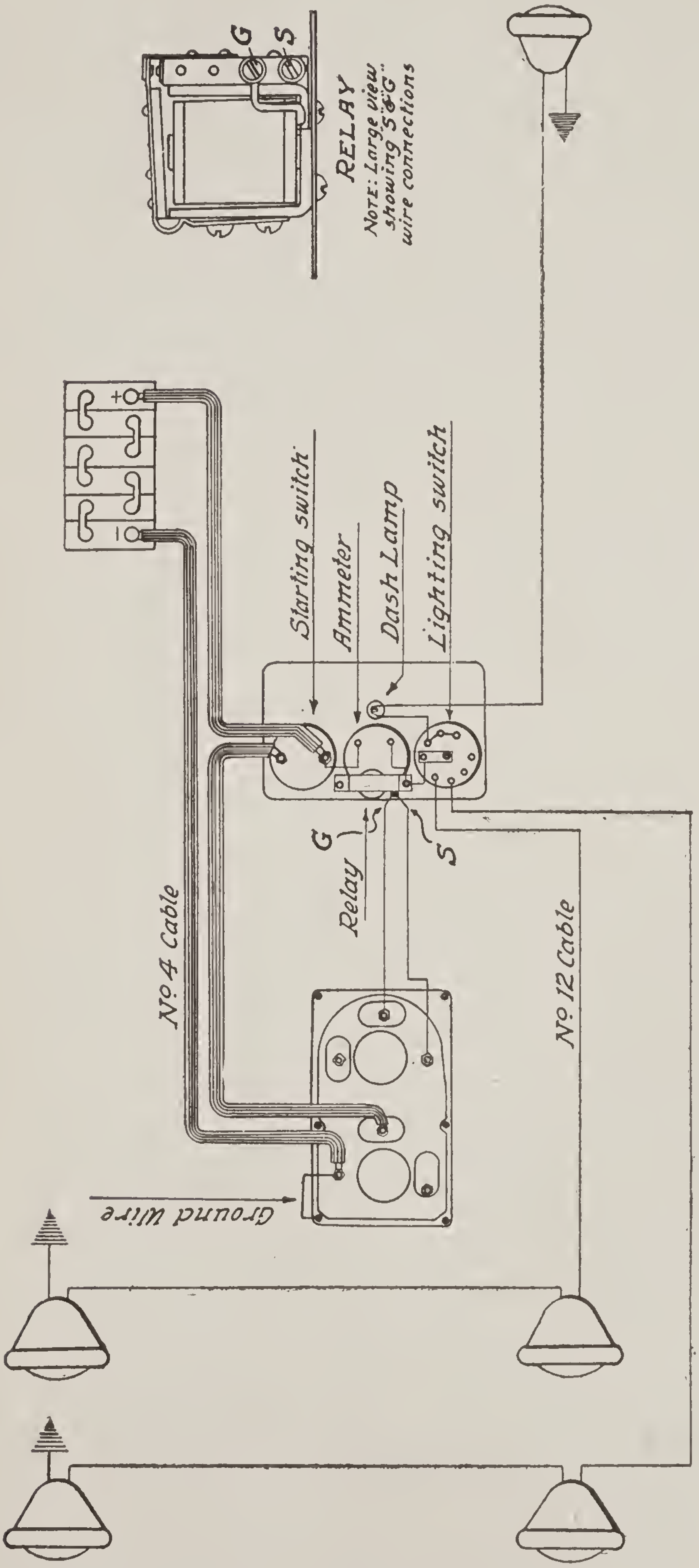


Fig. 405. Wiring Diagram for Fisher Ford Installation

Run the lighting cable from the lower brush *G* on the starting unit and connect to the terminal *G* on the relay. Connect another lighting cable from the post *S* on the generator to the post *S* on the relay. Run a lighting cable from the lighting switch to the side lamps, as shown, grounding one side on some metal part of the chassis. Take the wire running to the headlights from the original push-button switch on the car and connect it to the proper binding post on the new lighting switch. Connect the lighting cable

from one side of the dash lamp to the tail lamp, grounding one side of the tail lamp, as shown. When the wiring is finished as above outlined, test each circuit, making certain that all the connections have been made in accordance with the wiring diagram, Fig. 405. Solder and tape all the joints, and tighten all the terminals with a wrench. Close the ignition switch, press the starter button, and the engine should be turned over by the starting unit. As soon as the engine begins to run at a fair speed, the ammeter should indicate a charge going into the battery. Then stop the engine and turn on the lights; the ammeter should then show a discharge reading.

Operating Instructions. As is the case with the majority of Ford starting systems, the choker wire to the carburetor is taken from the front of the radiator and carried up through the dash. In cold weather it is always advisable to pull this wire and flood the carburetor when starting. Driving the starter with a loose chain is dangerous and should be avoided, so that the tension of the chain should be inspected at regular intervals until it has seen sufficient service to have stopped stretching. The starter—that is, the generator—must not be run with the battery disconnected unless the small wire *S* is removed from the binding post on the generator. No attempt should ever be made to start with the spark lever advanced. Instructions for the care of the brushes and the commutator, the location of short-circuits, grounds, and the like, will be found to be the same as those outlined in connection with the description of other Ford systems.

NORTH EAST

Preparing Engine. While a single unit of the chain-driven type, this differs from the others of this type already described only in the details of the chain drive. Remove the radiator and the water connections, the fan, the fan bracket, the screw for adjusting the fan, the fan pulley on the crankshaft, the starting crank, the timer rod for the advancing and the retarding ignition timing, one bolt holding the gear-case cover to make place for the stud 2394, and five bolts on the lower flange of engine base to make place for the bolts 2369, Fig. 406. Before removing the timer rod, carefully mark the timer housing and place a corresponding mark on the timing-gear case in order that the ignition timing of the motor may not be altered when the new timer rod, provided with the North East equipment, is installed.

Mounting Starter. The numbers for the various parts given in the following instructions for installing the unit, all refer to the illustration, Fig. 406. Place the chain sprocket 2374 on the crankshaft and fasten with the pin originally used for holding the Ford fan pulley; replace a split cotter pin in each end of the large pin for locking purposes, as in the original mounting. Then replace the starting crank. Screw the stud 2388 in place and lock it by passing a split cotter pin through the hole at the inner end. Be sure that the shoulder of this stud is brought up tight against the finished face on the timing-gear housing (casting), so that the stud will be in absolute alignment with the crankshaft.

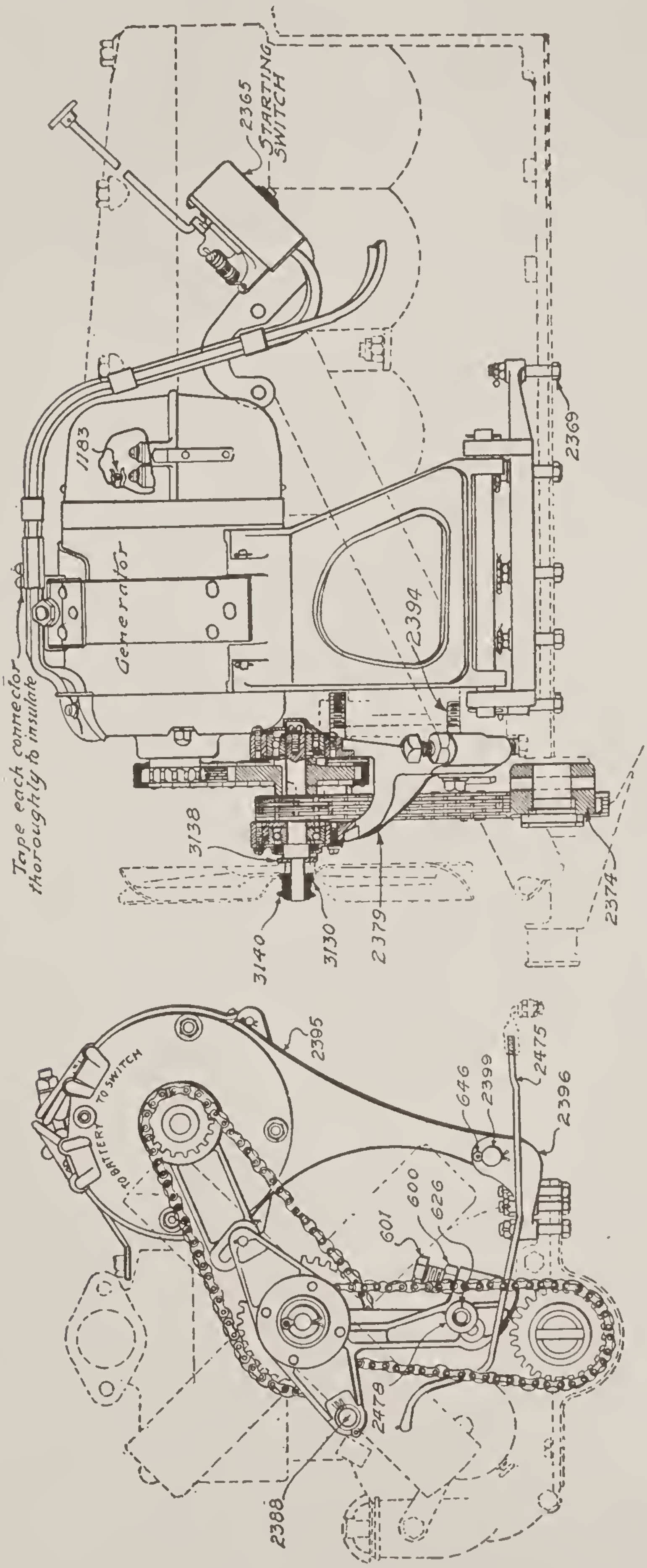


Fig. 406. Front and Side Elevations of North East Ford Installation
Courtesy of North East Electric Company, Rochester, New York

Screw the stud 2394 in place and lock it with a cotter pin. If the boss of the timing-gear housing at this point is rough, it should be smoothed down with a file before screwing home the stud. Fasten the hinge bracket 2396 by five bolts 2369, inserting them from below, and lock the nuts used on these bolts by split cotter pins; then assemble the cradle 2395 with the generator-motor unit in the hinge

bracket, being sure to place the split cotter pins at each end of the hinge pin 2399 for locking purposes.

If necessary to clear the sprocket bracket, chip off a slight amount of the vertical rib on the gear cover of the engine directly over the crankshaft bearing. Mount the assembled sprocket bracket 2379 on the studs 2388 and 2394. Be sure that one washer 2478 is placed on the stud 2388 before mounting the bracket; pay strict attention to see that there is no clearance between the shoulder of the stud and the bracket. If necessary, place filler washers on this stud so that no strain will be placed on the bracket when the nut on the clamp stud 2394 is securely fastened. *It is very necessary that the chain sprockets be in absolute alignment. Be sure to use a straightedge to make certain that the sprockets line up accurately.* This is very important. To take care of any longitudinal variation; filler washers are supplied for placing on the mounting studs between the sprocket bracket and the shoulders of the studs. These filler washers should be used if necessary to bring the sprockets into proper alignment. After the sprockets have been accurately lined up, mount the timer rod 2475.

Mount the horizontal chain by threading downward over the large sprocket on the countershaft (upper shaft), then around the motor-generator sprocket, and make the connection by inserting the master link from the rear. Then mount and connect the vertical chain in a similar manner. Make sure that the connecting links are properly locked after the loose side plates are in place. Adjust the vertical chain to a moderate tension by relieving the nut on the clamp stud 2394 and screwing down the adjusting screw 601, Fig. 406. After adjustment has been made, be sure to lock the adjusting screw by means of the jam nut and screw down the nut on the clamp stud which has been previously relieved.

To adjust the horizontal chain, release the clasp nut 626 and turn the generator toward the engine. This will take up the slack in the chain. Cut off the fan pulley with a hack saw so that the hub on the fan will be $\frac{3}{8}$ inch long, as shown in Fig. 406. Make certain that the one fiber washer 3138 is first placed on the shaft, then the fan, then another fiber washer 3138, then the two steel washers 3130 with the spring 3140 between them. Pressure should be applied to compress the spring until the cotter pin 646 can be dropped through the hole in the end of the shaft. This is important, as it forms a friction

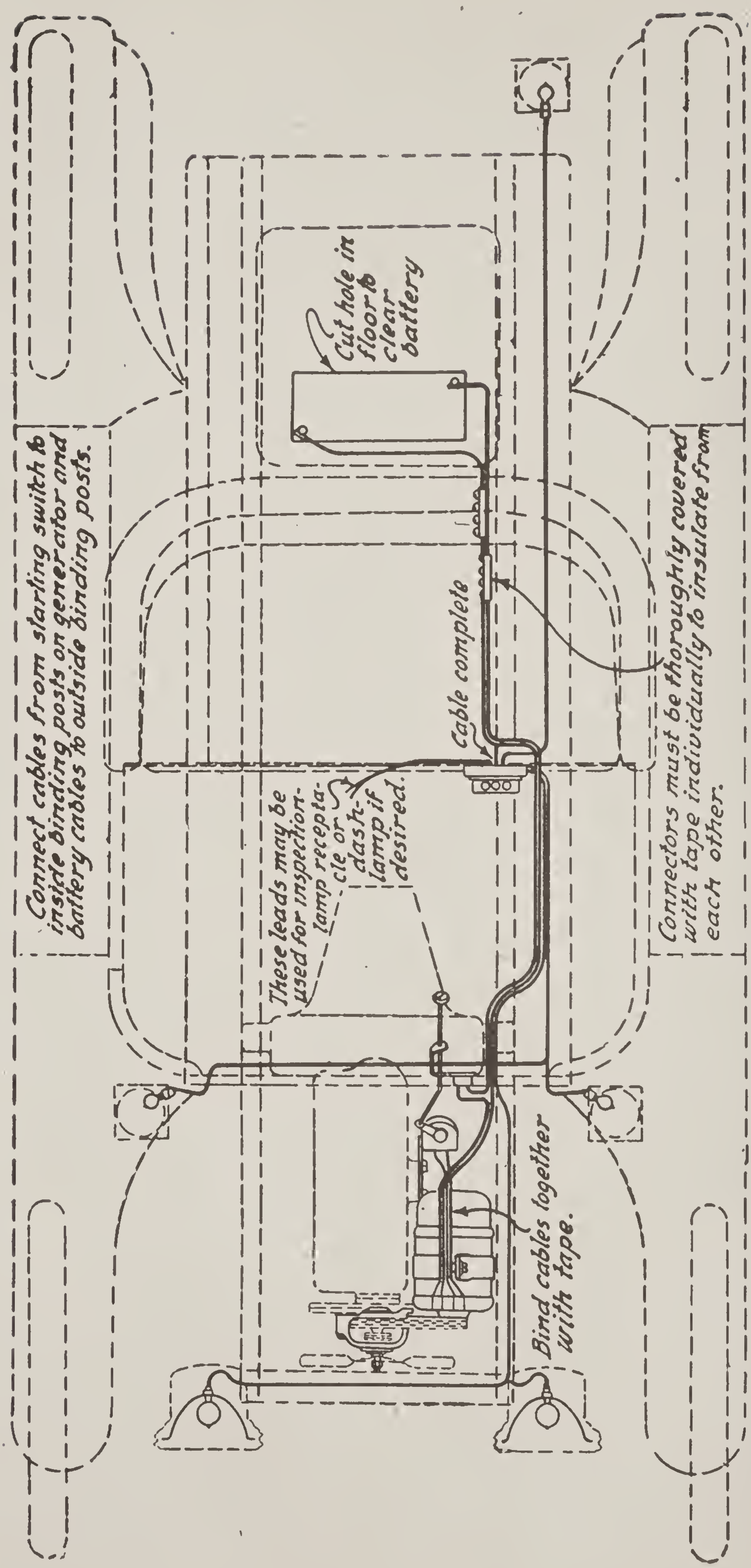


Fig. 407. Wiring Diagram for Complete North East Ford Installation

clutch strong enough to drive the fan and at the same time provides for a certain amount of relief to the sprockets, the chain, and the fan.

Turn the engine over by hand to inspect the working of the chain. Make careful examination to be sure that all the bolts and all the nuts are in place and properly fastened. Oil both the chains with a liberal amount of semi-liquid graphite grease.

Mounting Battery. Install the battery on the runabout, as shown in Fig. 407; on touring cars the battery should be mounted under the rear seat, as far forward as possible. To mount the battery, cut holes through the floor board of the car, large enough to clear the battery. Lay the board 3141, Fig. 408, on the upper face of the lower flange of the frame panels and bolt firmly by using steel clamping strips 3142 placed on the underside of the channel frame. Now fasten the battery in place by means of the hook bolts 2460, being sure

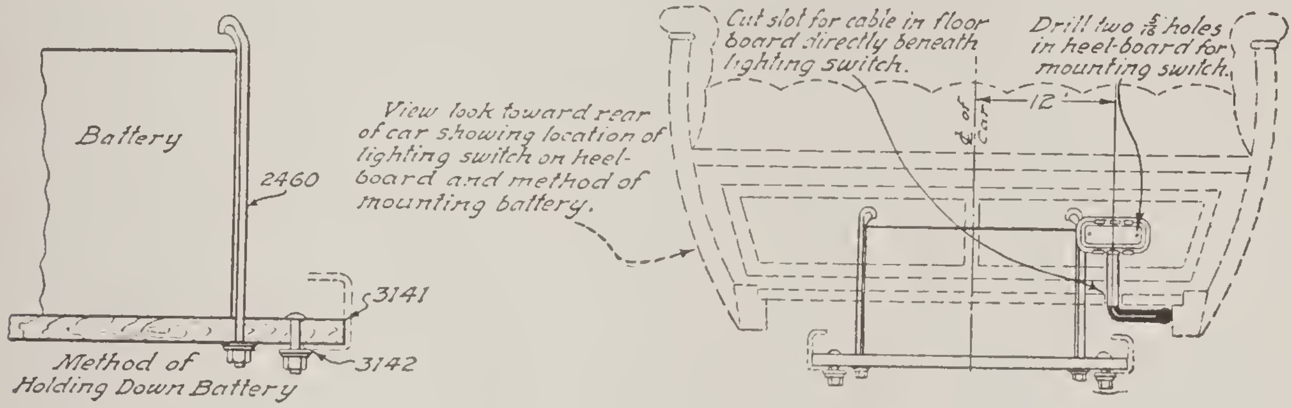


Fig. 408. Details of North East Switch Wiring

that the flat washers and the lock washers are placed between the board and the nuts on the bolts. If the muffler interferes, it is well to cut a groove in the board to clear it and to place a piece of asbestos sheeting between the board and the muffler.

When the car is not already equipped with electric lamps, it will be necessary to install new lights or to mount reflectors in the head-lights and adapters, or sockets, in the side and the rear lamps. Mount the lighting switch and run wires to all the lamps and to the battery location, but do not connect the wires to the battery as yet. Also run the wires to the motor-generator, Figs. 407, 408, and 409. Special care should be taken that all the wires are made fast to the wood body and that the insulation on the wires is doubly protected by tape or circular loom where the wires pass through the sheet metal. For fastening the wires, use leather cleats and insulated staples as supplied.

Replace the radiator, taking care not to omit the gaskets and the leather radiator seats, and, at the same time, mount the starting switch 2367, Fig. 406, by the bolts holding the flange of the return-water tube to the engine. After completing this, fill the radiator. Also mount the guide bracket 2368 for the starting button 2366, as shown in Fig. 409. Connect the switch wires to the motor generator, as shown in Figs. 406 and 407. Replace the floor boards, after notching them so as to clear the conduit running from the lighting switch downward. Carefully connect the battery wires to the two wires coming from the general circuit. Connect one lead at a time and carefully wrap the connector with tape before making another connection. Be sure to use plenty of insulating tape over these connections so that they will be well protected. After the connections have been made and insulated, see that the leads are properly fastened. If the wires have to be made longer to accommodate the coupé or the other special bodies, care should be taken to see that the extensions are made of the same size and type of wire that is used in the remainder of the system. Tight mechanical joints, well soldered and taped, should be made. The use of any smaller wire will prevent the proper operation of the system. Where possible to avoid it, the distance between the battery and the electrical unit should never be increased.

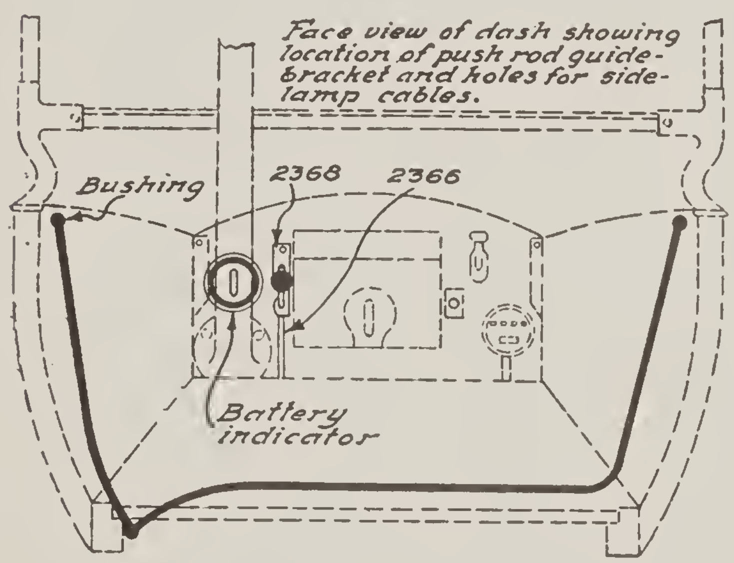


Fig. 409. Details of Dash Wiring for North East System

Operating Instructions. After the car has been run a few hundred miles, inspect the driving chains and, if necessary, adjust to take up any slack. This should be done at intervals until all stretch has been taken out of the chain. Inspect the chains carefully from time to time to see that nothing has disturbed their alignment. The chains should be kept clean by washing with gasoline every few weeks and applying a new supply of graphite grease to their inside faces. To adjust the vertical chain, release the nut on the clamp stud 2394 and screw down the adjusting screw 601, Fig. 406. Be sure to lock this

screw with the jam nut after adjusting. If after adjusting the vertical chain the horizontal chain requires further adjustment, loosen the clamp holding the generator unit and turn the latter in a counter-clockwise direction until the proper tension of the chain is secured, then re-tighten the clasp.

Inspect the wiring from time to time to make certain that none of the connections are loosening up, and when washing the car, see that no water is allowed to fall on the generator or on the wiring. See that the cover on the rear end of the generator is always tight in its place. This cover is detachable for the purpose of inspecting the brushes and the commutator. If necessary to remove the generator at any time, see that the terminals of all the loose wires are well wrapped with electric insulating tape. This is important, since if these wires should come in contact with each other or with the metal parts of the car, a short-circuit may occur and ruin the battery. In disconnecting the wires, be sure to tag them properly so that they can be replaced correctly, as improper connections may damage the system. The battery alone will supply the current for the lamps when the generator is removed from the car, but if used for any length of time with the generator off, the battery will naturally run down and have to be recharged from an outside source; care should be taken not to permit the battery to discharge too low before doing this.

If it should be necessary to run the generator with the battery disconnected from the system, *remove the small 10-ampere fuse 1183, Fig. 406, located over the brushes inside the detachable hood at the rear end of the generator, but be sure to replace this fuse when the battery is again connected.* If at any time the generator is not charging the battery properly, although the system tests out in good condition throughout, it is evident that the fuse 1183 has been blown and should be replaced by a new one of the same capacity. The purpose of this fuse is to protect the generator from injury. The bearings of the generator, when assembled by the manufacturer, are packed with a special lubricating compound, so that no provision is made for oiling them.

The lamps required are 14-volt 18-c.p. G-16$\frac{1}{2}$ bayonet-base bulbs for the headlights, and 14-volt 4-c.p. G-8 bulbs with the same type of base for the side and rear lights.

SPLITDORF

Preparing Engine. Disconnect all water and gasoline connections and the radiator brace rod, which should be pushed back through the dash out of the way, and remove the radiator. If the machine is fitted with electric lights, disconnect the wiring, Fig. 410. Remove the fan and its connections and then turn the engine over by hand until the pin holding the fan pulley on the crankshaft is perpendicular. This brings the pin over the hole in the engine base in position to be driven through it. Drive out the pin holding the dog clutch of the starting crank and pull out the crank, Fig. 411. Drive

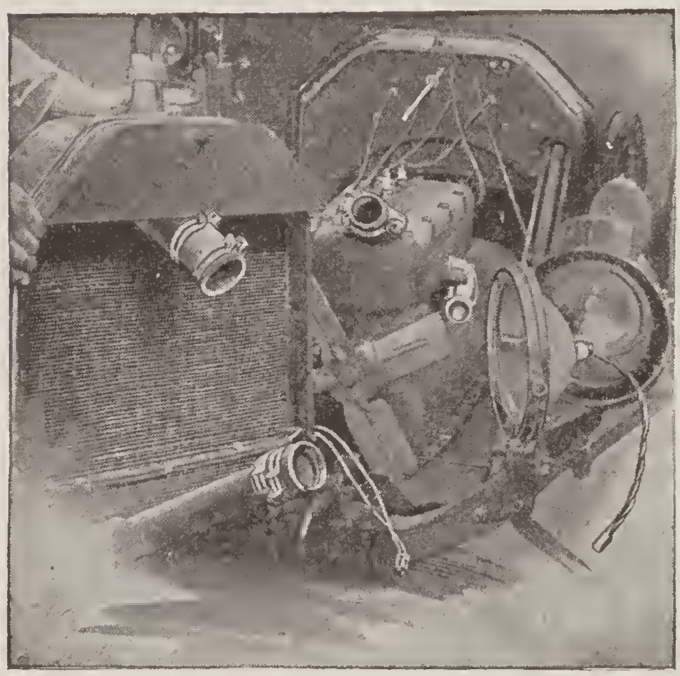


Fig. 410. Dismounting Radiator Lamps
Courtesy of Splitdorf Electric Company, Newark, New Jersey

Fig. 411. Removing Hand Crank and Fan
Courtesy of Splitdorf Electric Company, Newark, New Jersey

out the pin holding the fan pulley to the crankshaft, and a smart blow on the pulley itself will free it from the shaft. In case the pin is rusted in place, a little kerosene will help to free it.

Remove bolts B and C, Fig. 412, then loosen the nut A, but before removing it from the bolt tie a piece of twine around the bolt to prevent it from falling into the engine base or the crankcase. In case it should drop, it will remain in the hole, and a sharp tap directly beneath it on the crankcase will cause it to jump upward, when it can be caught with the fingers. Place the adjustable bracket in position and secure it to the engine, using new bolts supplied at B and C with the nuts formerly on the old bolts. The bolts and nuts holding the

lower part of the bracket must be carefully tightened, as it is important that this part be held firmly.

Mounting Starter. Place the split taper sleeve on the engine shaft, using a fine file if necessary to smooth off any burrs. Drive a pin through the sleeve and the shaft until it is flush with the sleeve on both sides. With the key in position, place the sprocket on the sleeve, registering the keyway with the key. A nut is then turned on to draw the sprocket up on the taper sleeve, and it also causes the sleeve to grip the crankshaft securely.

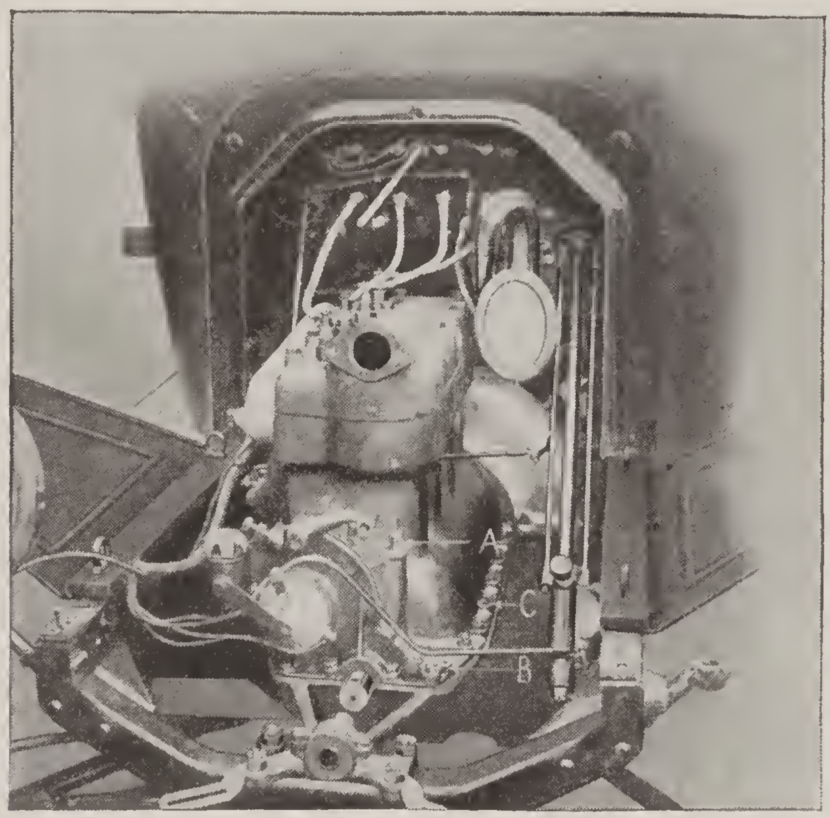


Fig. 412. Placing Adjustable Bracket in Position
Courtesy of Splitdorf Electric Company, Newark, New Jersey

Replace the starting crank, start the chain under the sprocket in mesh, and with the aid of the crank turn the engine over slowly until the chain is drawn through for about half of its length, making certain that the chain is working freely, Fig. 413. Then fasten the generator-motor unit to the adjustable bracket with the three bolts and lock washers furnished. This can be accomplished easily by tilting the bracket. Pass the chain over the generator sprocket, joining the chain with the pin and locking the pin with a washer and cotter pin. Align the crankshaft and generator-motor sprocket by means of the adjustable bracket hinge bolt. Adjust the chain to its proper tension, i.e., without any slack. The chain should never be allowed to run in

a slack condition, as it may break. Adjusting screws on the bracket provide an easy means of keeping it at the right tension.

The fan pulley furnished with the outfit is an aluminum die-casting in two parts and is designed to clamp over the Ford fan pulley. It is held on by four screws and lock washers and brings the center in line for the fan belt. Fill the recess of the fan with grease and replace the fan, using the original bearing stud; place the belt on the fan pulley and on the generator-motor pulley and adjust to proper tension. Like the chain, this pulley should be so tight that there is no undue slack, but tightening it too much should be guarded against,

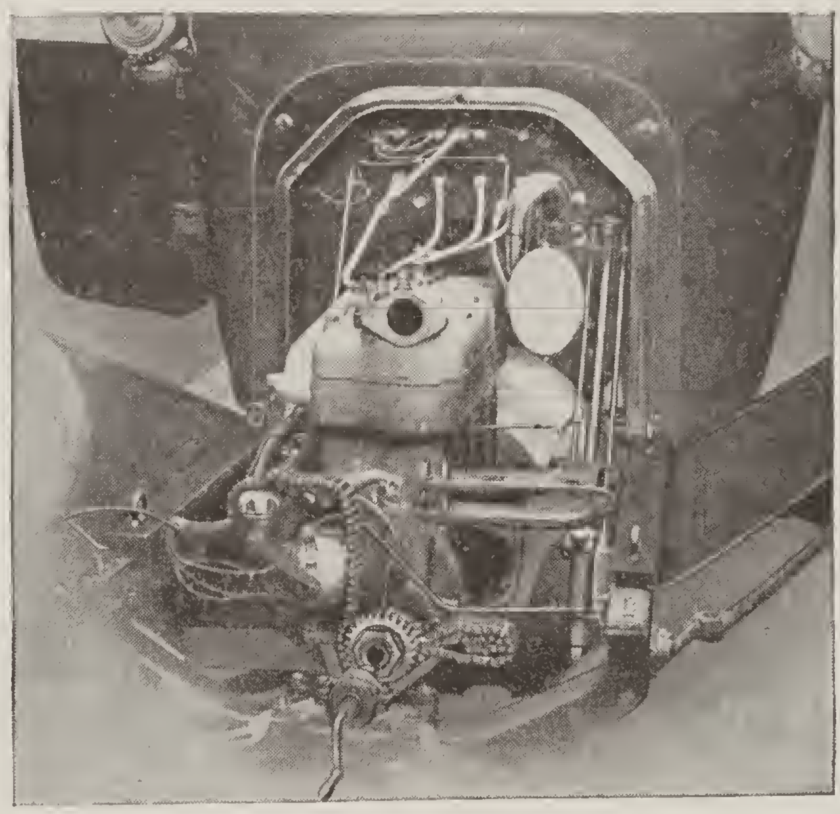


Fig. 413. Adjusting Driving Chain
Courtesy of Splitdorf Electric Company, Newark, New Jersey

as this only places an excessive strain on the shafts and does not make the fan run any better.

Wiring. The details of the various holes to be drilled or cut and the wiring to be installed are given in Figs. 414 to 419. Prepare the dash for the wiring, as shown in Figs. 415 and 416, which give the location and sizes of all holes—*A*, Fig. 416, for the ignition switch, *B* for the lighting and dimming switch, and *C* for the wires leading to the indicating automatic switch (battery cut-out with indicator to show whether the battery is charging or not). Unless a magneto is used for ignition, *A* may be omitted.

Bore a $\frac{7}{8}$-inch hole in the permanent floor board, as shown in Fig. 414, following the dimensions there given for its location. Install

the starting switch with the front of the switch lengthwise with and facing the right-hand side of the car, Fig. 419, and at the same time

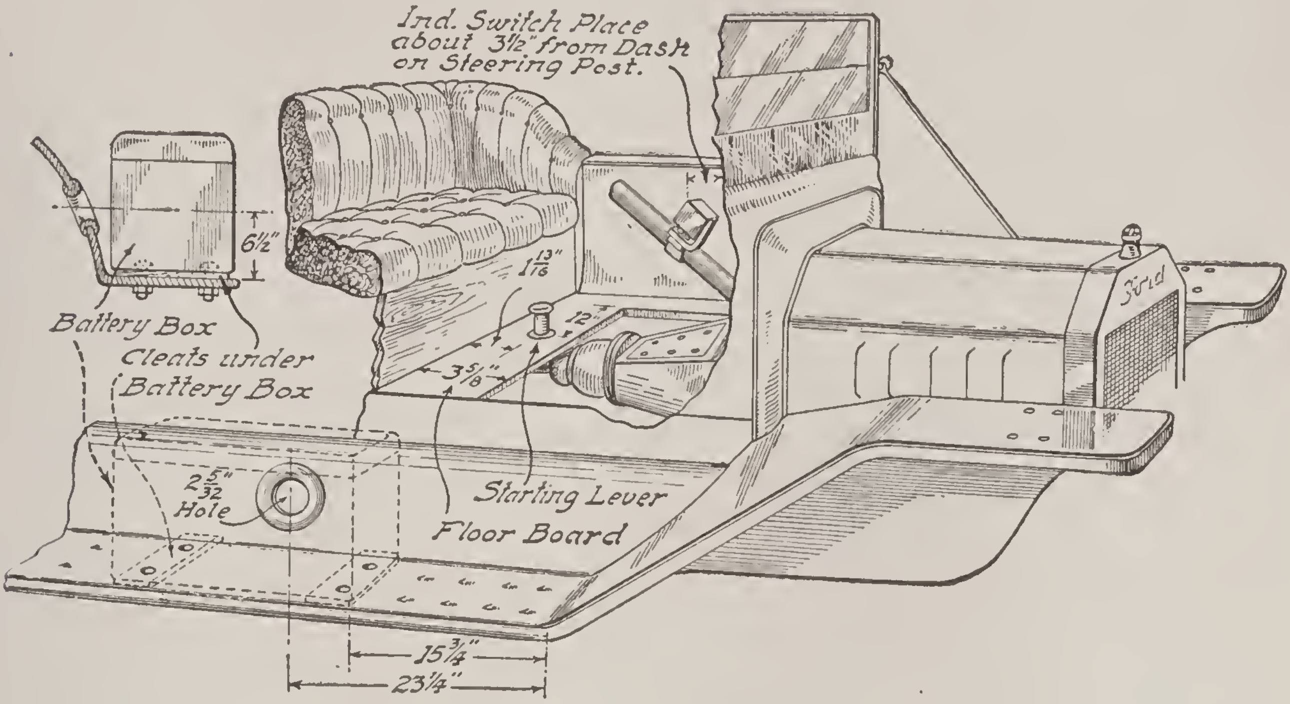


Fig. 414. Details of Wiring for Splitdorf Ford Installation

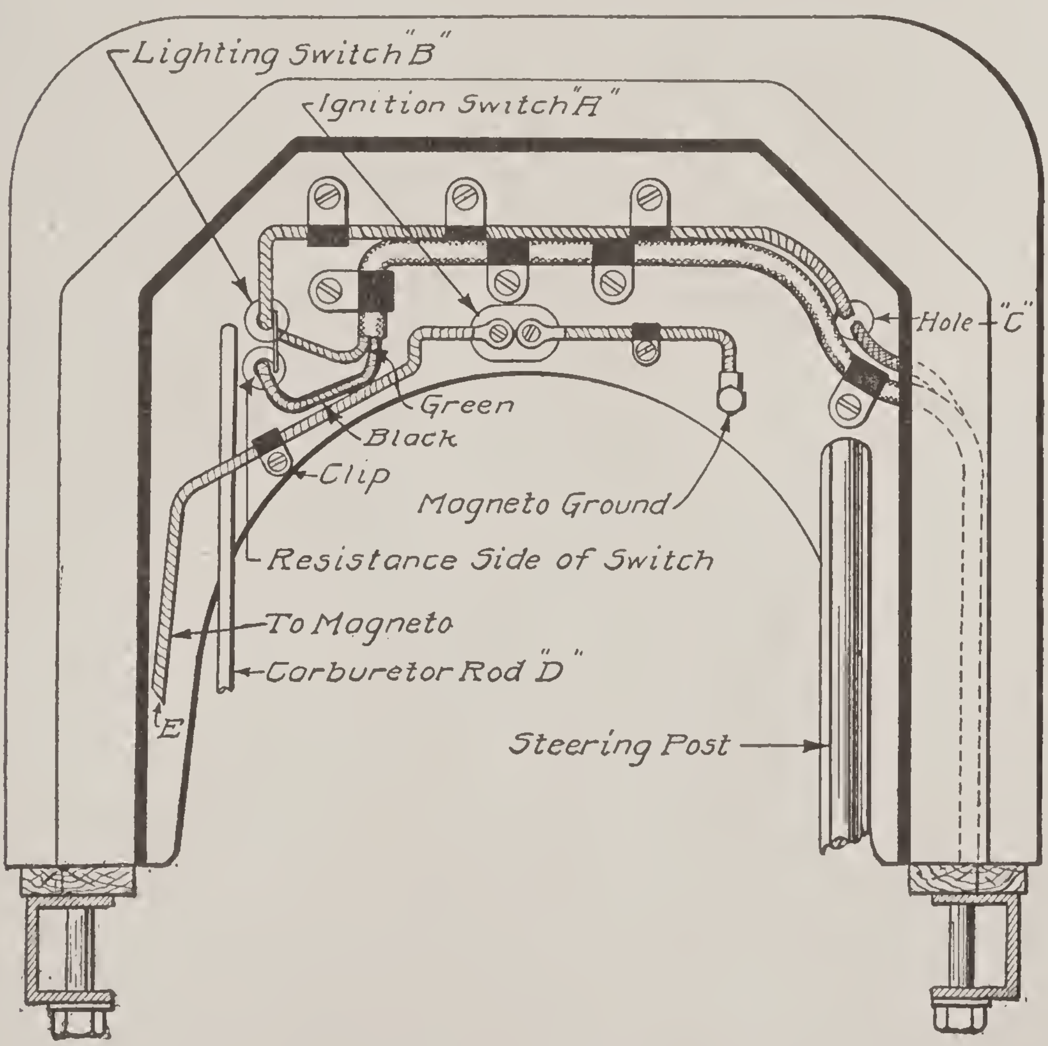


Fig. 415. Details of Wiring on Dash

the light-dimming switch should be placed in position with the coil end of the switch facing down. All wire terminals are marked to

correspond with similar marks on all parts of the installation. Lay wiring assembly in the sill of the car, as shown in Fig. 419, connecting the wires to the front of the dash, as in Fig. 415. (Reference to Fig.

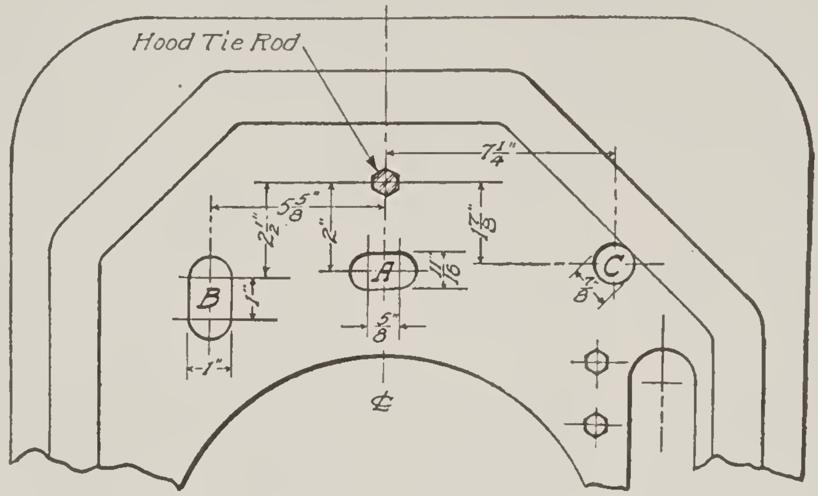


Fig. 416. Layout of Drilling on Dash for Ford Installation

418 will facilitate the installation.) Connect wires to indicating automatic switch in accordance with diagram on the back of the switch, after which fasten the switch to the steering column about $3\frac{1}{2}$ inches from the dash. Connect wires, as marked, to corresponding

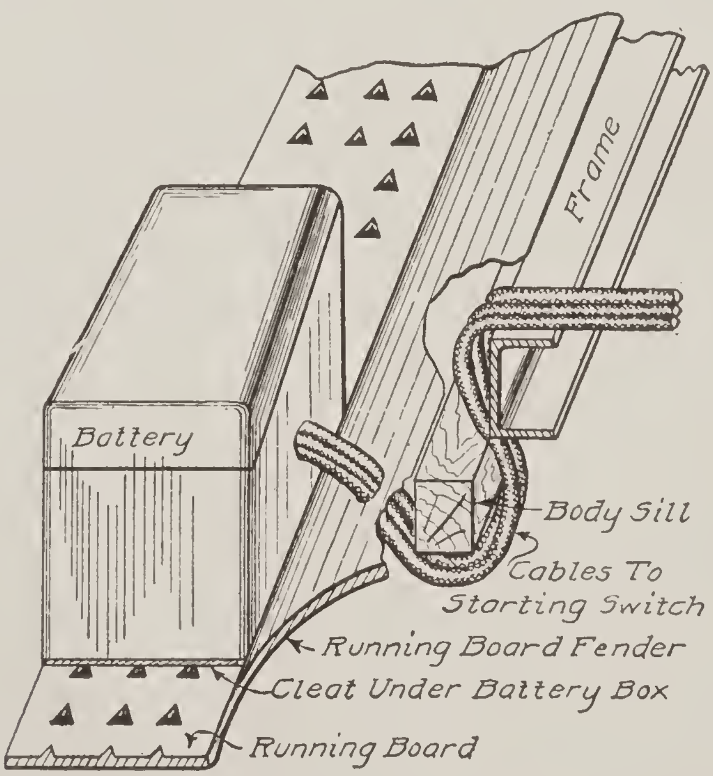


Fig. 417. Method of Running Cables from Batteries on Splitdorf Installation

terminals on the generator-motor and likewise to the starting switch. Prepare the curved running-board guard, or apron, for the battery leads and the running board for securing the battery box in accordance with the instructions given on Fig. 414. Place the battery box

on the running board, resting it on the two wood cleats and fasten it down with the bolts, nuts, and lock washers furnished.

Place the battery in the box with the outside terminals toward the car. Pass the extension cables under the wood sill of the car body and over the channel steel frame of the car, connecting the extension leads from the battery to the starting switch, as marked. The method of passing the cables around the sill and frame are shown in Fig. 418. After connecting the cables to the battery, cover all the

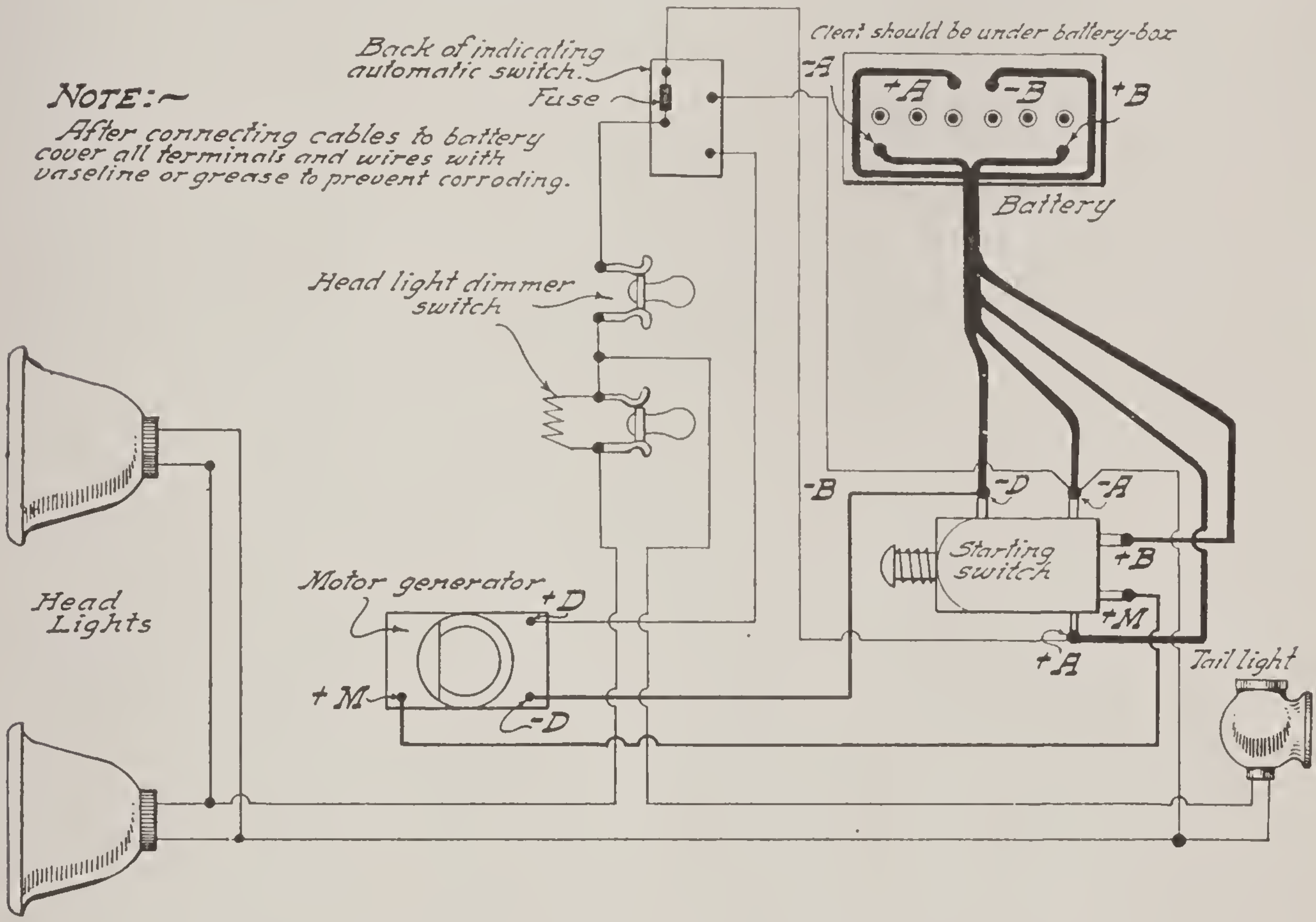


Fig. 418. Complete Wiring Diagram for Splitdorf Ford Installation

terminals and exposed parts of wires with vaseline or grease to prevent corrosion.

Wiring Diagram. In the wiring diagram, Fig. 418, double wiring is used throughout, so that there are no ground connections. When the engine is running so that the unit is operating as a generator, the current flows from terminal $+D$ on the generator to a similarly marked terminal on the indicating switch, through the voltage coil of the battery cut-out, and thence to the terminal $+A$ on the switch, where it divides, one side leading to $+A$ on the battery and through the battery to $-A$ on the starting switch. The other half of the current flows through a jumper in the switch to $+B$ on the starting switch, through to the same terminal on the battery, and through the battery to $-B$ on the starting switch. It will be noted that

the common return points of the current at the starting switch are $-B$ and $-D$, and from there the current flows to $-D$ on the generator.

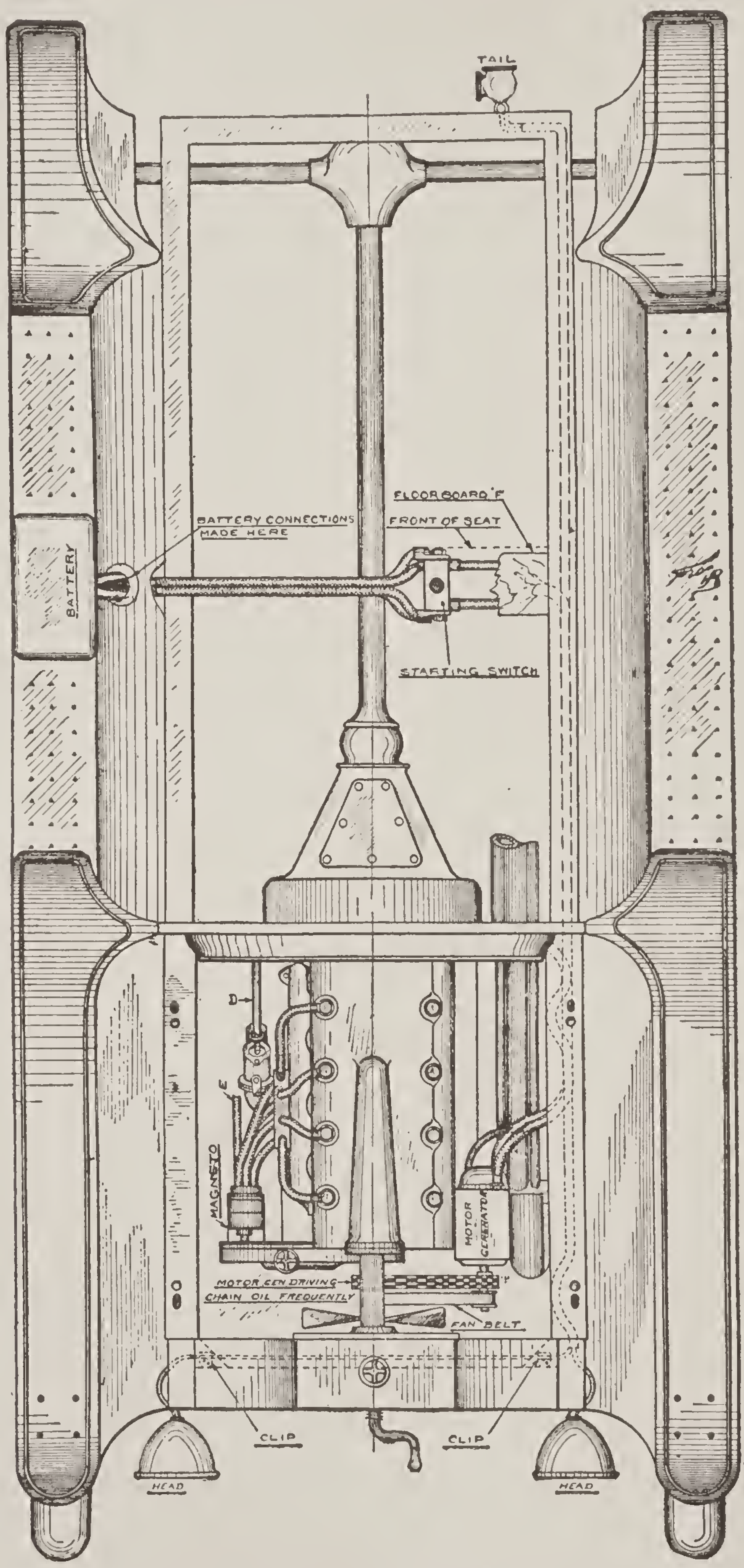


Fig. 419. Plan of Ford Chassis, Showing Installation of Splitdorf Starting Switch

Starting Switch. When the starting switch is closed by depressing its foot button, the current flows from $+A$ at the battery to $+A$

on the starting switch, through the switch to $+M$ on the switch, and thence to the terminal $+M$ on the motor, through the latter to $-B$ $-D$ on the starting switch, and then to $-B$ on the battery, through the battery to the $+B$ terminal, and thence to the $+B$ terminal on the starting switch, through the switch to $-A$ on the switch, and thence to the $-A$ terminal on the battery, and through the battery to $+A$, completing the circuit.

Instructions. *Generator-Motor.* See that the unit is lined up accurately so that the chain runs perfectly true. If this is not done, the chain will be noisy and will wear abnormally on one side and eventually break. A poorly aligned chain will also wear the sprockets. Watch the chain carefully during the first hundred miles or so of running and, as often as required, take up any slack that appears until the chain seats itself. The life of the chain will be greatly prolonged by keeping it well lubricated and at the proper tension. If for any reason it becomes necessary to remove the battery from the car, the engine must not be run without first connecting terminals $-D$ and $+D$ of the dynamo with a piece of copper wire.

The commutator should be kept clean by wiping at regular intervals with a clean rag; if it becomes blackened, note whether there is undue sparking between the brushes and the commutator and, if necessary, sand-in the brushes to correct this. Use No. 00 sandpaper for this and also for brightening up the face of the commutator itself. After this operation, remove all traces of carbon, sand, and metallic dust from the commutator housing as well as from the spaces between the commutator segments. Do not change the position of the brushes or alter the tension of the brush springs unless they have weakened after one or more years of running. See that the brush leads do not rub against the armature, as this will chafe the insulation off and cause a ground or a short-circuit. The generator-motor should be oiled about every thousand miles, using five to six drops of good light oil in each oil hole. See that the fan belt is running true on the pulleys, otherwise it will ride the flange of the pulley and either fly off or break.

Starting Switch. If the brushes of the switch wear unduly, see that the foot button of the switch is not sticking in the floor board. The hole through which the rod of the button operates should be large enough to prevent the pedal spring from rubbing against the

floor board. The switch sticking down will cause both its own brushes and those of the generator-motor to burn and wear badly. See that when the starting-switch pedal returns to its normal position proper contact is made. This can be determined by removing the cover of the switch.

Indicating Automatic Switch. When the engine is running very slowly, the dial may indicate ON and OFF in rapid succession, fluttering continually. This is caused by the engine running at, or very close to, the speed at which the battery cut-out is designed to operate, so that no attention need be paid to it. Should this fluttering occur at medium or at high speeds, it indicates a loose connection in the wiring, either on the generator line, on the back of the cut-out, or in the starting switch. This, if neglected, will cause the contact points of the battery cut-out to burn badly, so that all connections should be gone over regularly to see that they are kept tight. As the generator output is controlled by means of a reversed compound field winding, or bucking coil, there is no regulating device combined with the battery cut-out. The battery has six cells, all of which are connected in series for starting, giving current at 12 volts. For both charging and lighting, the cells are coupled in two units of three each in series-multiple, so that 7-volt lamps are used. They are protected by a fuse on the back of the battery cut-out.

WESTINGHOUSE

Preparing Engine. Adjust the ignition and the carburetor so that the engine fires evenly and regularly before beginning the installation. Remove the radiator and water connections, three forward left-cylinder head bolts, and the fan and bracket timer. Turn the engine shaft until the pin in the fan pulley is in a perpendicular position *h*, and then remove the starting crank and the fan pulley, Fig. 420. Use a bulldozing tool to expand the front end of the engine oil pan, Figs. 421 and 422. (This tool is obtainable from the Westinghouse Company.) It is very important that at least $\frac{3}{8}$-inch clearance beyond the sprocket be obtained, as shown in Fig. 433. Be sure to use the bulldozing tool with the spacing hub *XI*, Figs. 421 and 422, always next to the engine case. The tool is made in two parts and is reversible so as to be available for right-hand and left-hand operations.

Mounting Starter. The crankshaft sprocket *H* is assembled by the manufacturer and adjusted to the correct tension. Dismantle the

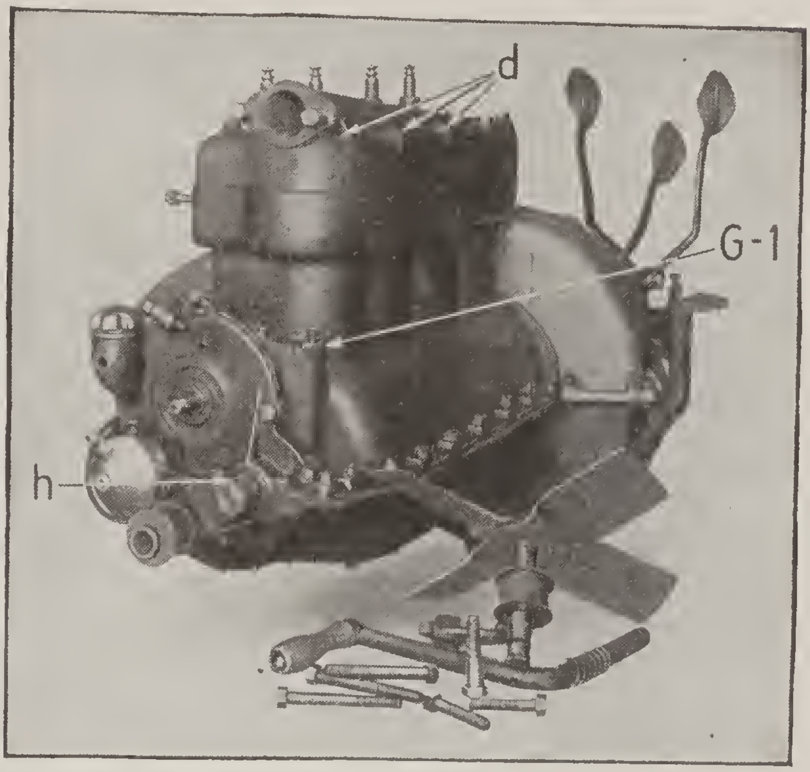


Fig. 420. Ford Engine Ready for Installation of Westinghouse Electric Equipment

sprocket. See that the pin hole in the crankshaft is in a vertical position *h*, Fig. 420, and then drive the new sprocket hub *H*, Fig. 423, in place so that the hole in the sprocket is in line with the hole in the

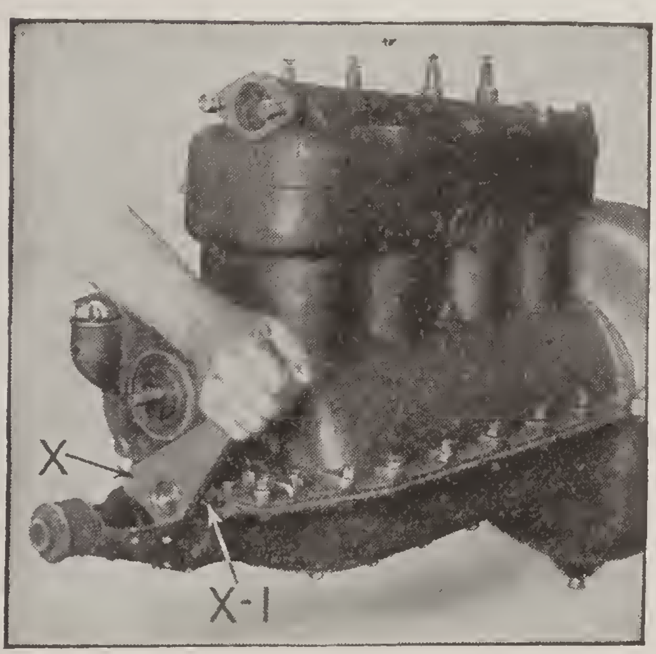


Fig. 421. Use of Bulldozing Tool on Westinghouse Ford System

Fig. 422. Using Hammer to Help Bulldozing Tool

crankshaft. The sprocket hub must be a tight fit on the crankshaft and should be driven into place by means of copper or brass bar, as

shown at *b*, Fig. 423. Drive the pin *H-1*, Fig. 424, through the sprocket hub *H* and the shaft, and be sure that the head end is flush with the surface of the hub. If the pin *H-1* is not a tight fit in the

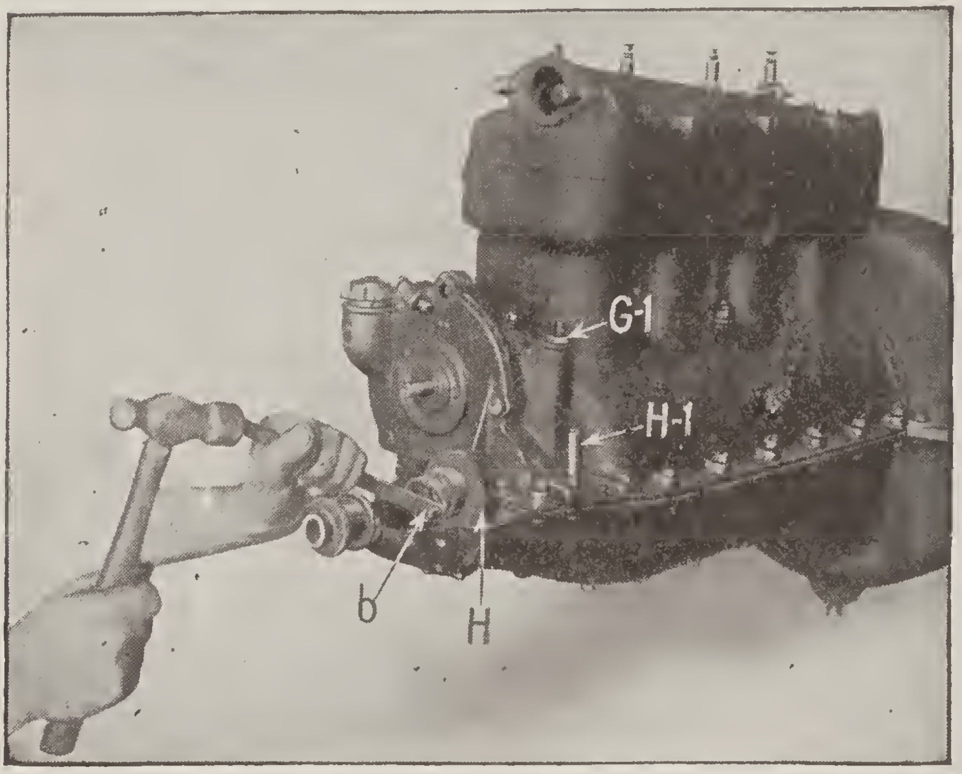


Fig. 423. Putting on Crankshaft Sprocket Hub in Westinghouse System

shaft, it should be bent slightly at the center to make it tight. Use a drift for driving pin *H-1* into place so as not to injure the pin or the

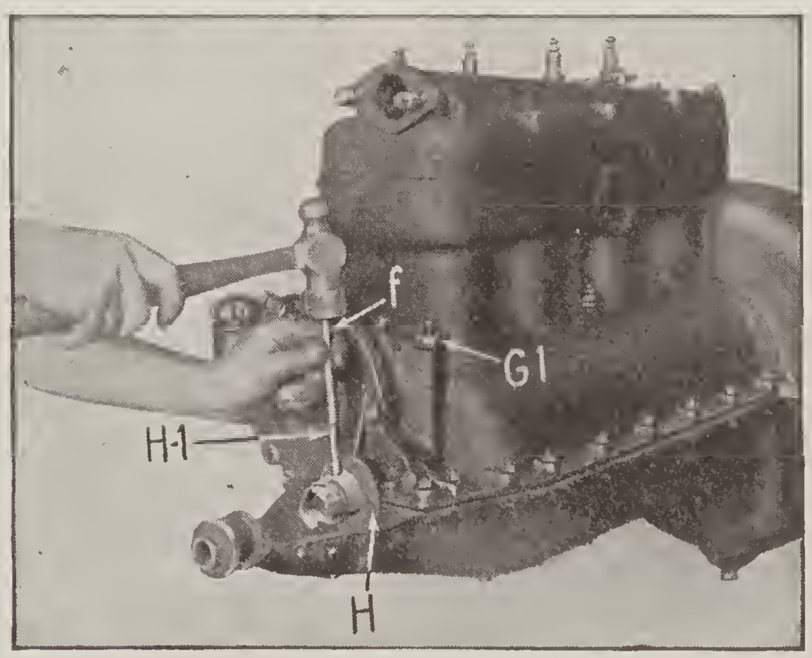


Fig. 424. Inserting Sprocket Pin with Drift

hub. To be sure that the pin *H-1* in not projecting too far at the extended end, place the sprocket *H-4*, Fig. 425, on the hub and turn it several revolutions. If it does not turn freely, the pin *H-1*,

Fig. 424, probably strikes the inside of the sprocket, and therefore the pin should be trimmed until it just clears.

Remove the sprocket *H-4* and place one of the friction collars *H-5* on the hub. Now spring the spring ring *H-2*, Fig. 425, into place on the hub *H*, so that the small hole in the ring engages with the projecting end of the small pin. It will not go into place any other way. *Be sure that the free end of the spring ring projects at least $\frac{5}{16}$ inch out from the surface of the sprocket hub*, Fig. 425. Place the chain *I* under the sprocket hub. Slide the sprocket *H-4* over the spring ring. Pack the sprocket with good cup grease and place the other friction washer *H-5* on the forward side of the sprocket. Now place the stationary washer *H-6* over the keyway in the sprocket hub and put the spring washer *H-7* on the outside of this and fasten it in place with the nut *H-8*, as shown in Fig. 425. The nut *H-8* should be tightened until the mark "O" on the nut corresponds with the mark in the keyway *a* on the hub, Fig. 426. The grooves in the face of the nut should register with the flukes of the spring washer.

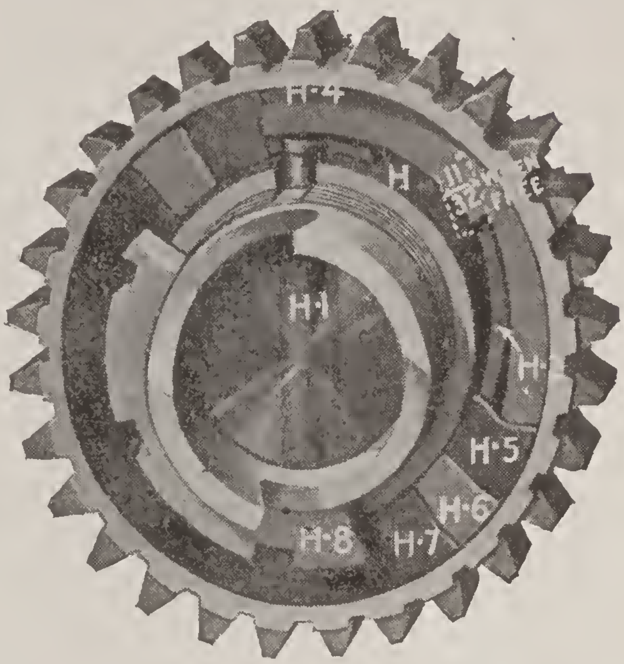


Fig. 425. Assembly of Westinghouse Crankshaft Sprocket

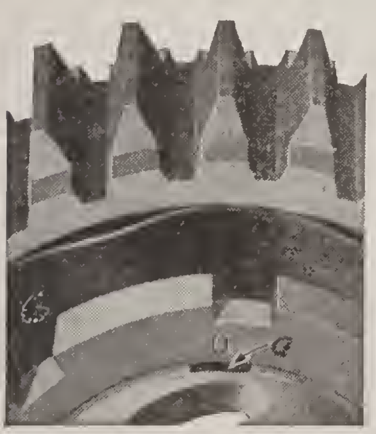


Fig. 426. Detail of Sprocket Showing Adjustment

Remove the nut from the forward left-hand bearing bolt and replace it with a special flat Westinghouse nut *G-1*, as shown in Fig. 420. Place the lock washer *G-2* on top of this nut and screw the cylindrical nut *G* down tight with the lock washer. Replace the Ford timer. Set the Westinghouse electric unit *A*, Fig. 427, in place on the engine, using in the cylinder head the three special screws *D* (furnished for this purpose) and the special cylindrical nut *G* (provided). Adjust the center distance between the engine crankshaft and the electric-unit shaft, as shown in Fig. 427. The distance should be $11\frac{25}{32}$ inches, as shown, and *all three points of support* should touch.

Remove the sprocket *B* from the electric unit shaft, Fig. 428. Insert the sprocket in the endless driving chain *I* and press the

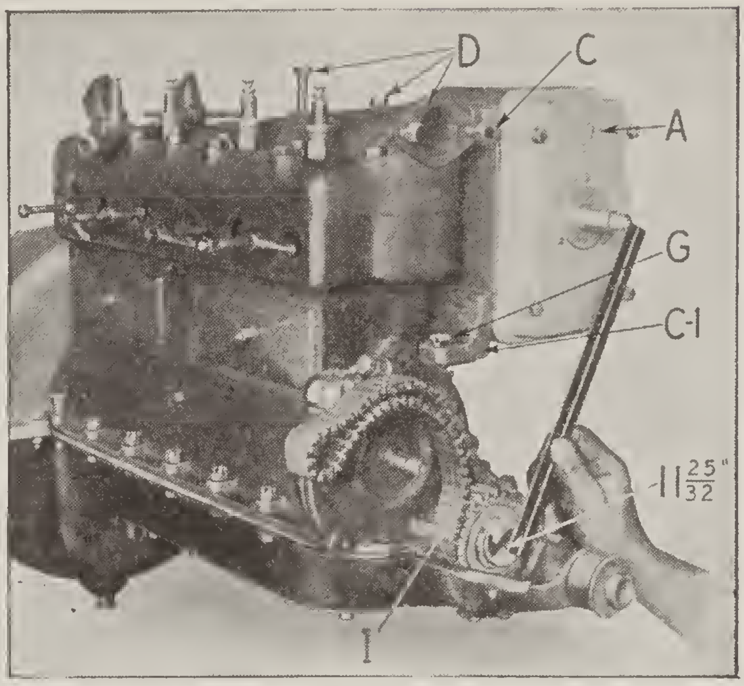


Fig. 427. Adjusting Distance between Centers of Crankshaft and Motor Shaft

sprocket on the shaft, as shown. When the sprocket is in place, there should be *at least 10 pounds tension on the chain.* If the tension is

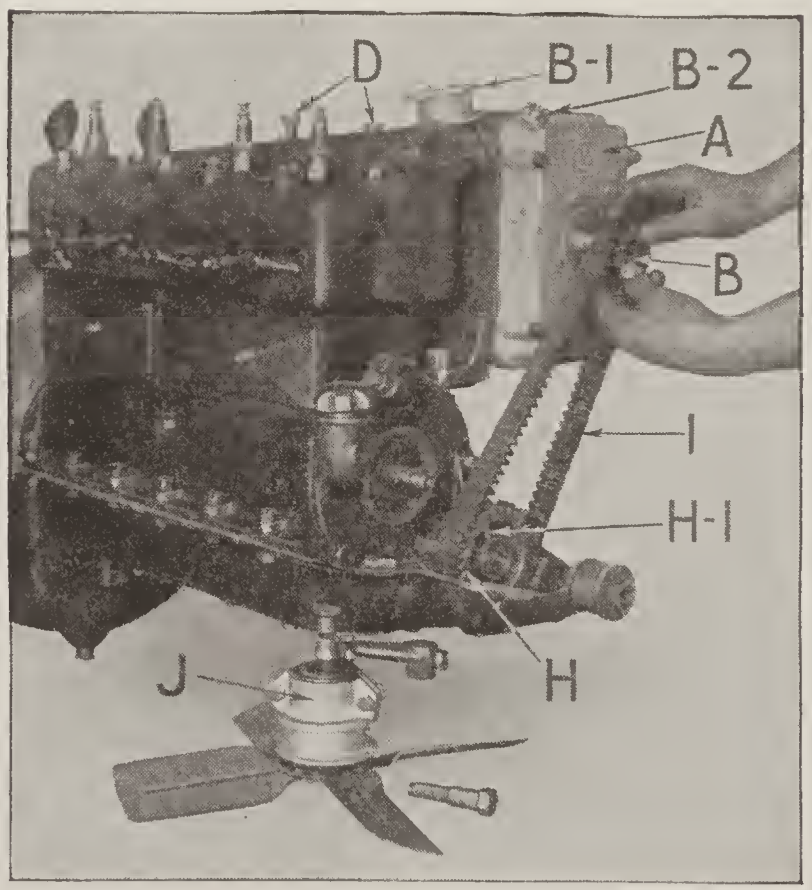


Fig. 428. Putting on Shaft Sprocket and Chain

less than 10 pounds, adjust the center distance as directed until the required tension is obtained. A new silent chain is elastic to some

extent, and, for this reason, a new chain is adjusted to run under the tension mentioned. After running about 2000 miles, the chain may be loose enough to strike the chain guard. This is a warning to tighten

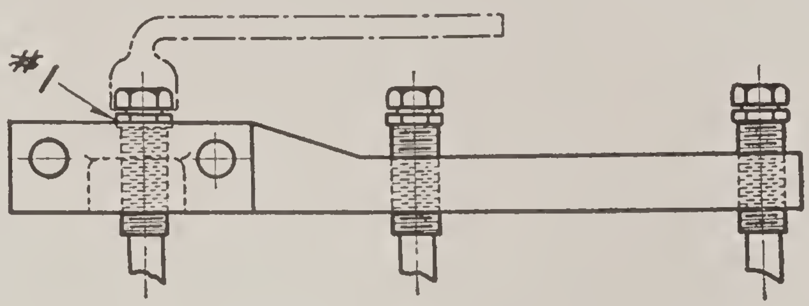


Fig. 429. Diagram Showing Chain Adjusting Bolts

the chain. To do this, loosen the three bolts, Fig. 429, about one full turn from the top supporting bracket. Tighten the adjusting bushings nearest the radiator until the tension is correct. Set the other bushings to agree and tighten all the support bolts. *Do not run*

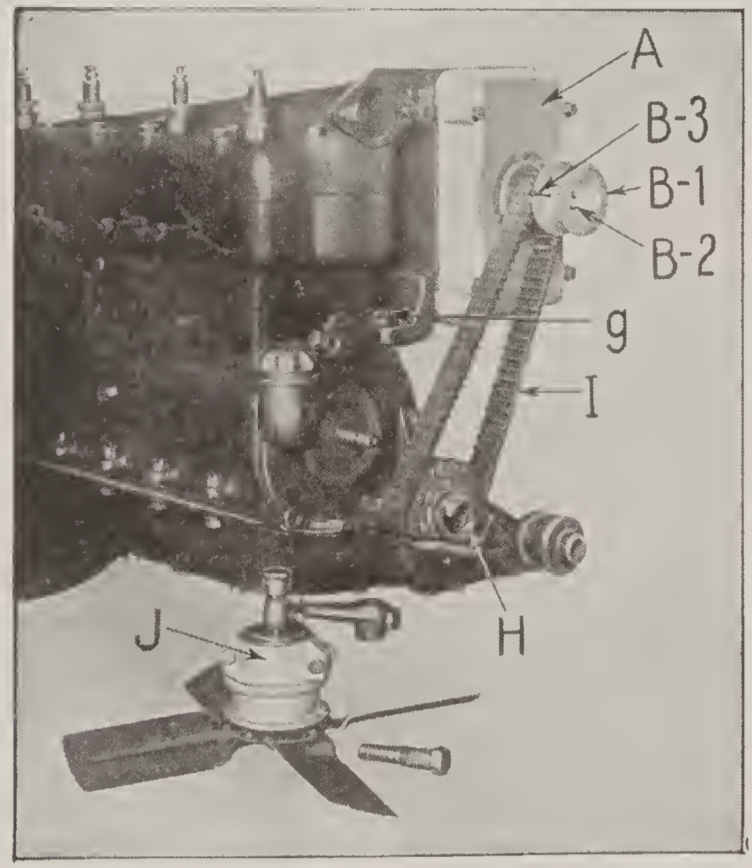


Fig. 430. Tightening Mounting Bracket with Shaft Pulley in Plates
Courtesy of Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania

the chain under tension after the first adjustment. This is very important. If the chain is too tight, it will produce a grinding noise. When properly adjusted, the chain should be so loose that when pressed on with the finger it will give about $\frac{1}{2}$ inch.

After replacing the fan pulley *B-1* and tightening the nut *B-2*, be sure to replace the cotter pin *B-3*, Fig. 430. Mount the chain guard

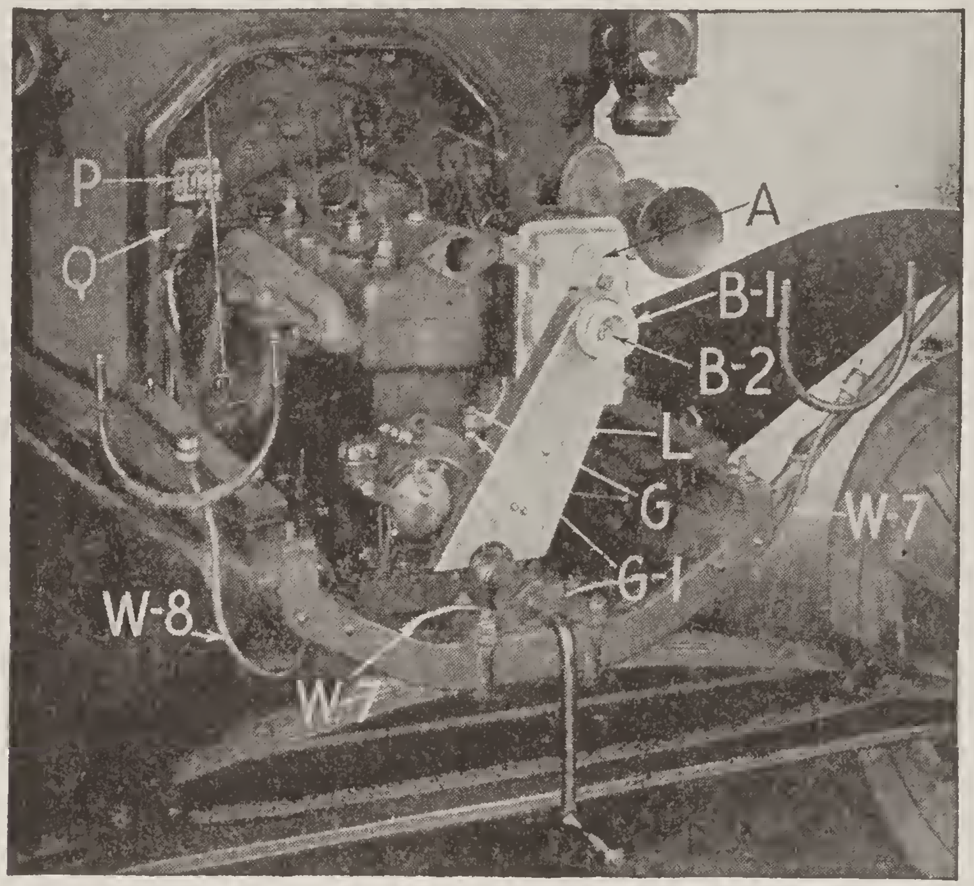


Fig. 431. View of Westinghouse Installation, Showing Chain Guard and Part of Wiring Arrangement

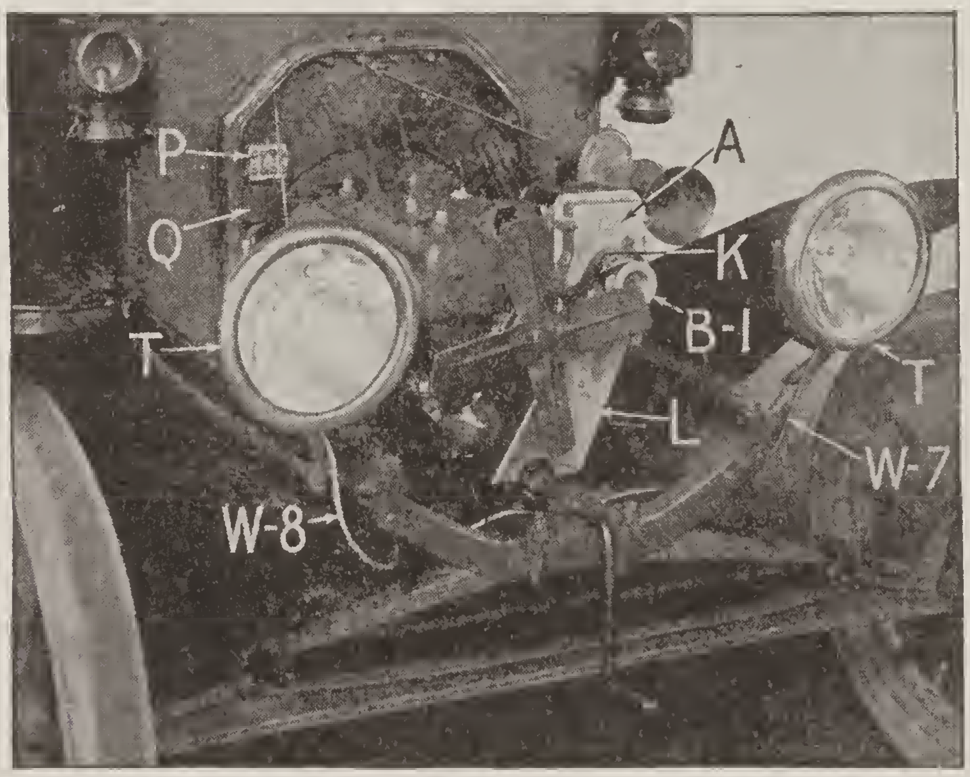


Fig. 432. Fan in Place and Headlights Mounted

L on the unit and see that it lines up, as shown in Fig. 431. Clamp the split fan pulley *J* on the Ford fan pulley, as shown in Figs. 428 and 430, and replace the fan on the engine, using the new fan belt *K*,

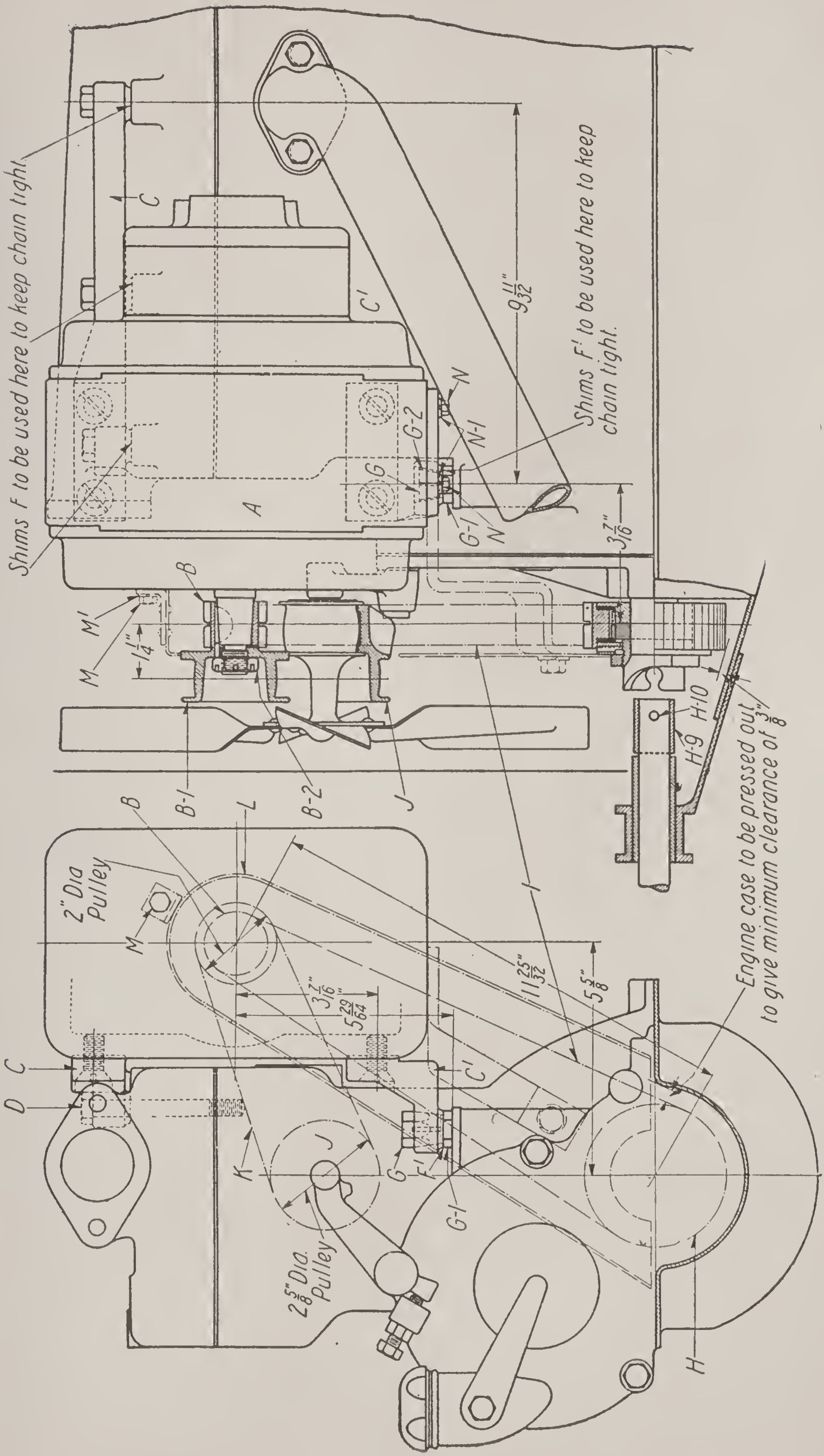


Fig. 433. End and Side Elevations of Westinghouse Ford Installation, Showing Correct Position of Parts on Engine

Fig. 432. Bend the fan blade slightly to clear the electric unit. Instead of the Ford cranking claw and pin, use the Westinghouse sleeve *H-9* and pin *H-10*, respectively, Fig. 433. When the Ford starting crank is replaced, it may be found slightly out of alignment. Insert a bar in the starting-crank bearing and spring the bearing into alignment. This completes the installation of the unit itself.

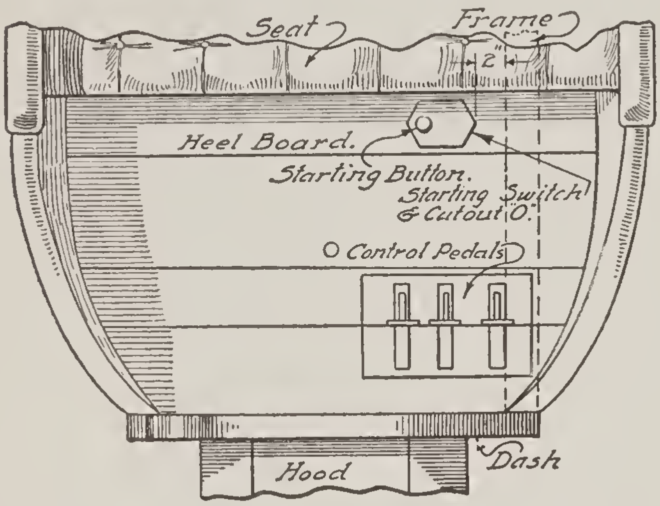


Fig. 434. Diagram Showing Mounting of Starting Switch and Cut-Out

Lighting and Starting Switches. Mount the two-gang lighting switch *P* on the right-hand side of the dash. Cut a rectangular hole in the dash at a point low enough so that the carburetor adjusting rod will not touch the contact screws of the switch when it is fastened in place by means of four wood screws to the cover plate on the face of the dash. Mount the fuse *Q* just below the lamp switch on the engine side of the dash, as shown in Fig. 431. Note that on 1915 Ford cars the new cowl dash may make it necessary to change the location of the speedometer slightly in order to provide space for the lamp switch.

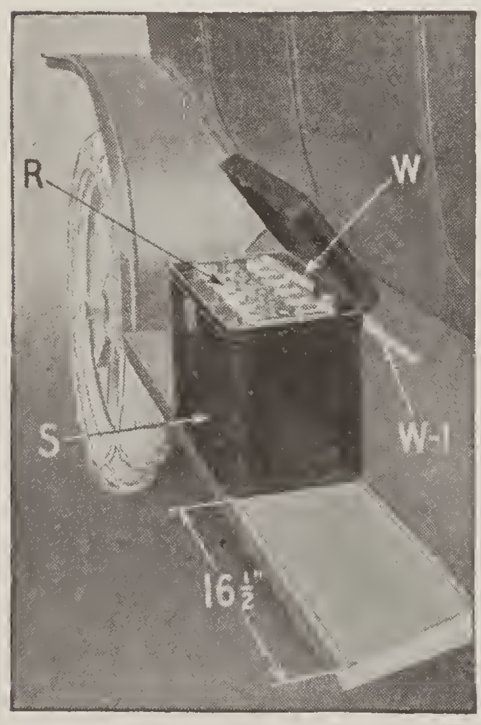


Fig. 435. Method of Mounting Battery Box on Right Running Board in Westinghouse System

The starting switch and generator cut-out *O*, Fig. 434, should be located on the heel board at the left-hand side of the car, approximately 2 inches from the car frame. The terminals should be toward the right side of the car. Mount the battery box on the right running board, as shown in Fig. 435, and drill two $\frac{3}{4}$-inch holes in the mud shield to match the holes in the battery box, Fig. 436, and fasten down with the holding-down bolts.

Wiring. The wiring should now be fastened in place, as shown in Figs. 437 and 438. If Westinghouse lamps are used, the dimmer should be removed. Except where wood screws may be used to

attach holding cleats to wood parts, all the holding cleats should be fastened under the bolts already on the Ford chassis. *Be very careful that the cable terminals do not touch any part other than the studs to which they should be fastened.* Carelessness in this particular will result in burned-out apparatus and may actually ruin the battery before the car is ever run. It is equally essential to prevent the metal armor on the cables from touching any of the connecting studs or the terminals. The ground wire should be fastened at one end under one of the supporting bolts of the starting switch and cut-out and at the other end by fastening the connection together with a cleat under the bolt holding the brake and clutch rod to the frame. *Do not connect the ground wire from the battery until all the other wires are in place and fastened.* The ground connection of *W* is made by fastening the connection under a bolt of the muffler support

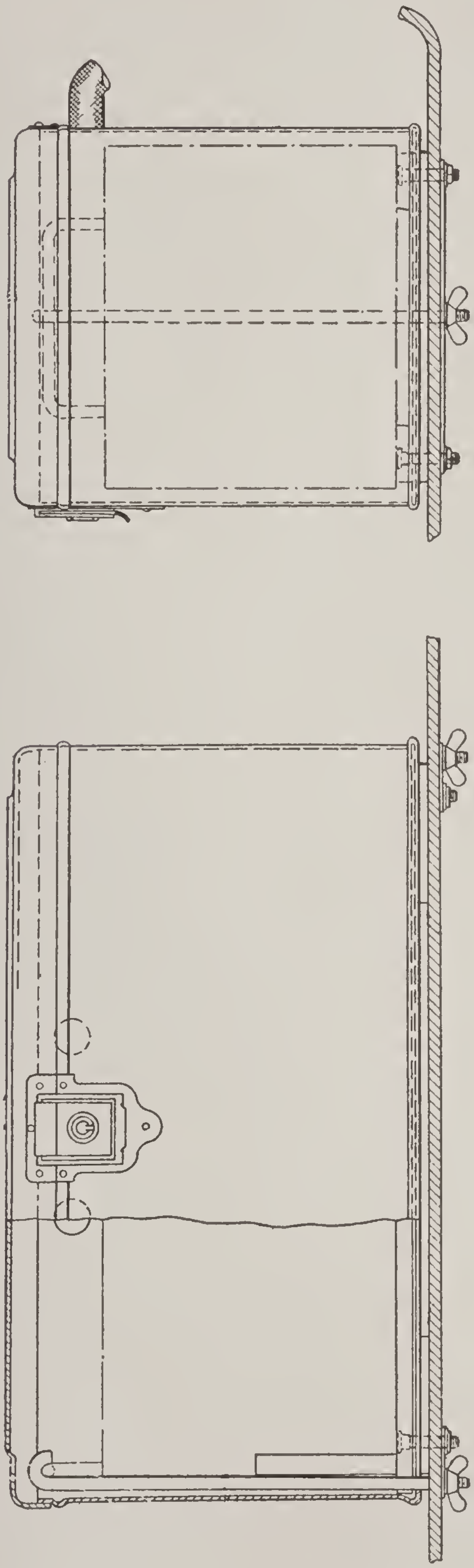


Fig. 436. Side and End Views of Battery Box Mounted on Running Board
Courtesy of Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania

Attach the lamp connections to the wires. These are of the solderless type which are connected by removing the connector from the lamp, Fig. 439. Slip the casing *a* back over the cable and push the wires through the collar *b*. Strip the insulation from the wire about $\frac{1}{4}$ inch back from the end. With a small screwdriver applied to the sleeve *d*, remove the little metal socket *c* from

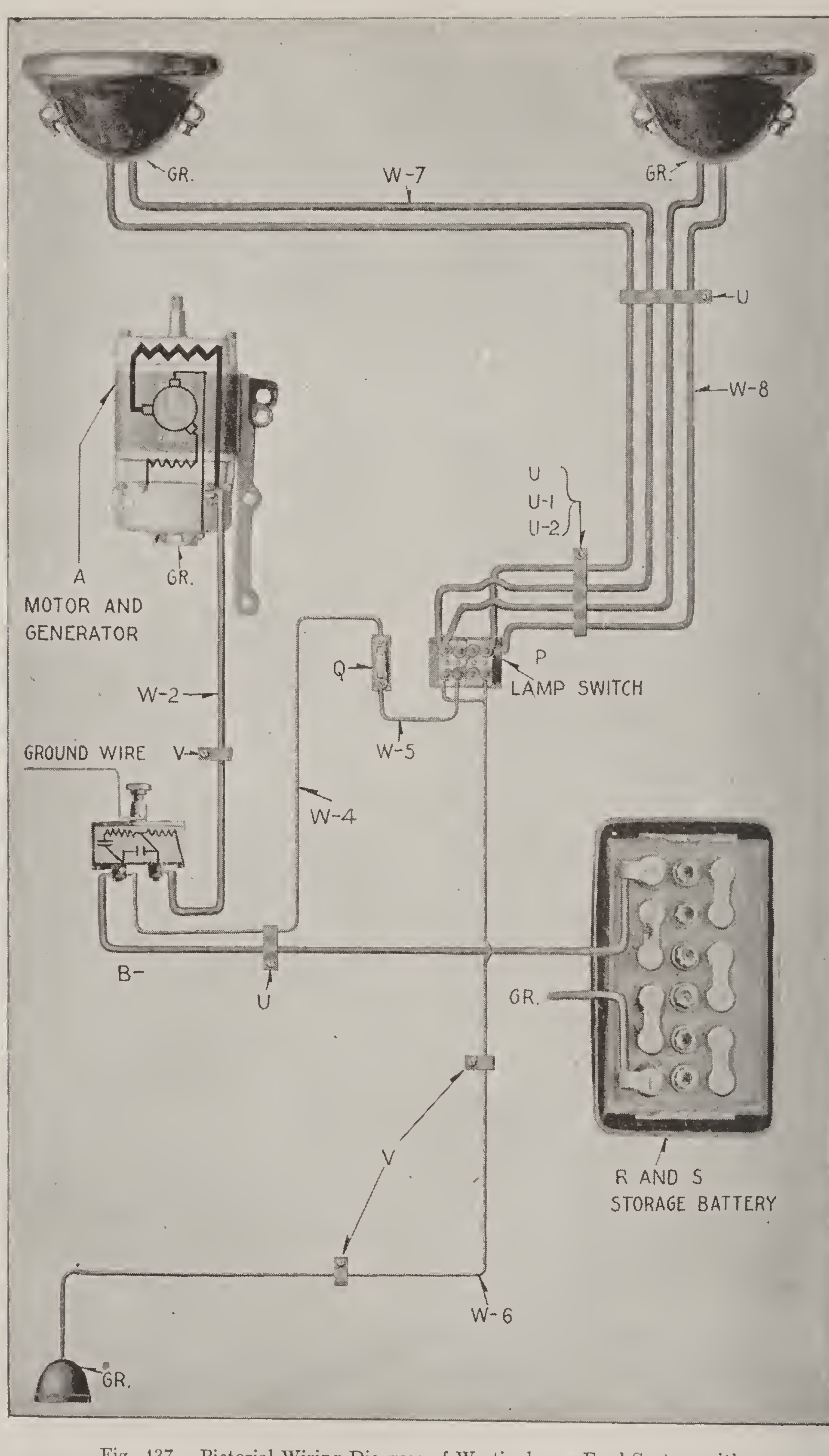


Fig. 437. Pictorial Wiring Diagram of Westinghouse Ford System with Other than Westinghouse Ford Lamps

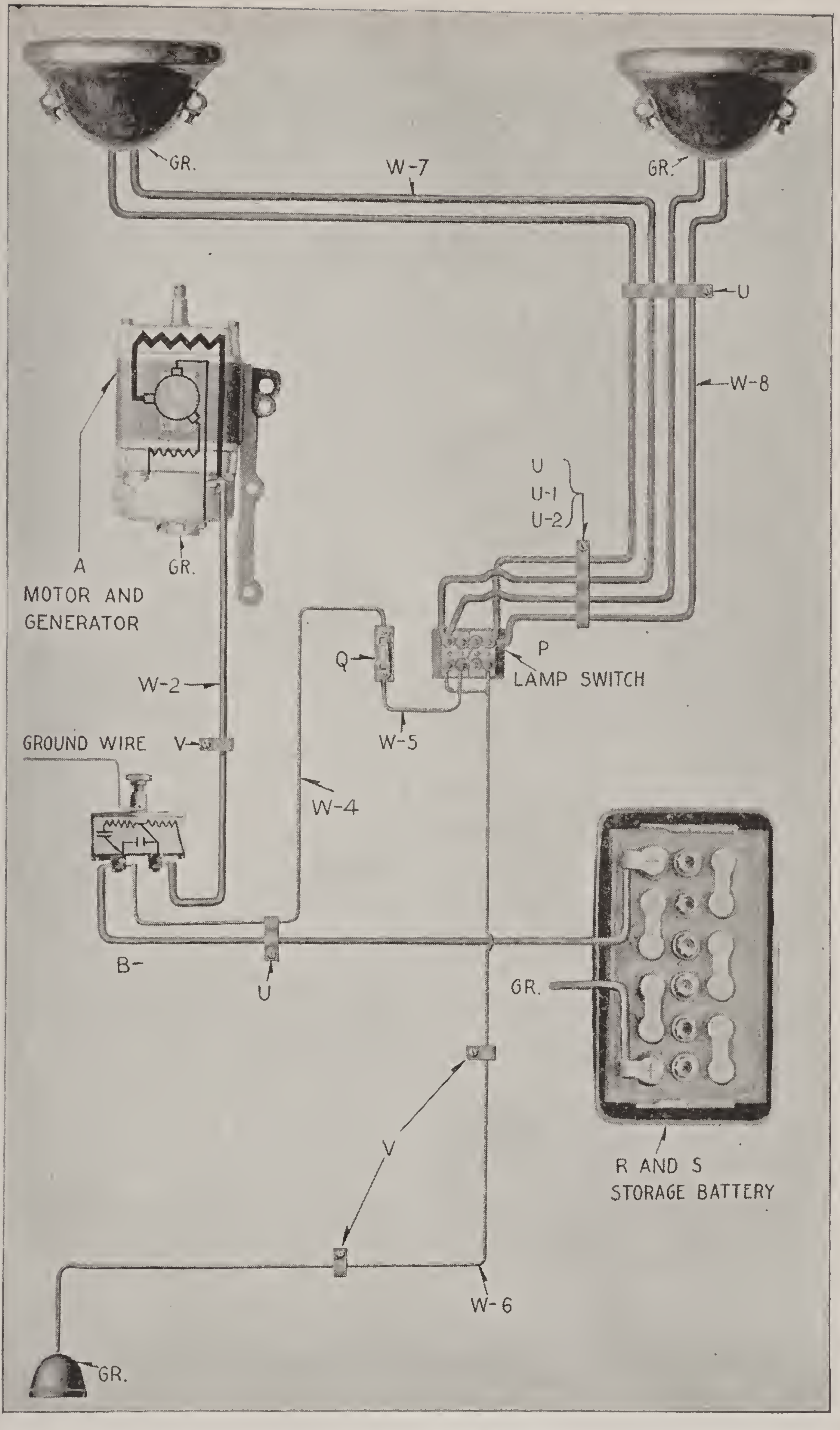


Fig. 438. Pictorial Wiring Diagram for Westinghouse Installation when Westinghouse Ford Lamps Are Used

the connector. Insert the bare ends of the wire in the socket and fasten with small set screws. Replace the socket and fasten it by screwing up on the sleeve *d*. Be sure that none of the strands of the wire project outside of the insulation piece *e*. Attach the head and tail lamps, insert the connecting plugs, and try all circuits to determine if everything is operating satisfactorily.

When Westinghouse Ford electric head lamps are used, Fig. 438, connect them as shown in the diagram, grounding one wire from each lamp, also one wire from the tail-light socket. One switch button will give a dim light and the other switch will give a bright light. If other than the above lamps are used, such as the double-bulb two-wire type headlights, one wire from each lamp socket must be grounded to the lamp housing or the car frame, and the dimmer should be disconnected. If side lights are used instead of double-bulb headlights, with two-wire (double contact) lamps, both wires in cables *W-7* and *W-8* can be used for the headlights, as shown in the diagram for the Westinghouse Ford lamps. The dash end of one wire in each cable must be grounded instead of connecting it to the switch. An additional wire from the switch should be run to one terminal in each side light, and the other lamp terminal should be grounded. The dimmer should then be disconnected.

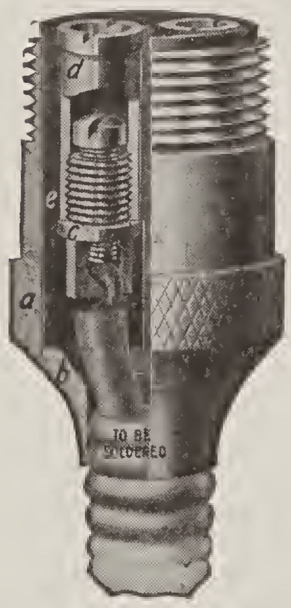


Fig. 439. Details of Westinghouse Lamp Connector

If side lights are used instead of double-bulb headlights with single-wire lamps, both ends of one wire in the cables *W-7* and *W-8* are useless and should be taped up. An additional wire from the switch should be run to each side light.

Westinghouse Ignition. *Assembly.* If the Westinghouse ignition system is also to be installed, it should be assembled in place at this time, i.e., before replacing the Ford timer housing, the radiator, and other parts, which have been removed to install the electric starting and lighting unit. Remove the timer, or spark advance, rod; the steel bush; the Ford roller contact; the coil box; and all ignition wiring. Place the Westinghouse gear *Z-1*, Fig. 432, on the camshaft in place of the Ford timer roller contact, and fasten it in place with the same pin, cap, and nut used to hold the roller contact. Take out the spark plug of the first cylinder. Turn the engine over until

the piston of cylinder No. 1 is exactly at the upper dead center on the firing stroke, that is, when the piston is at the top of the cylinder *with both valves closed.* The position of the valves and the piston may be seen through the spark-plug hole. Mount the ignition unit in the

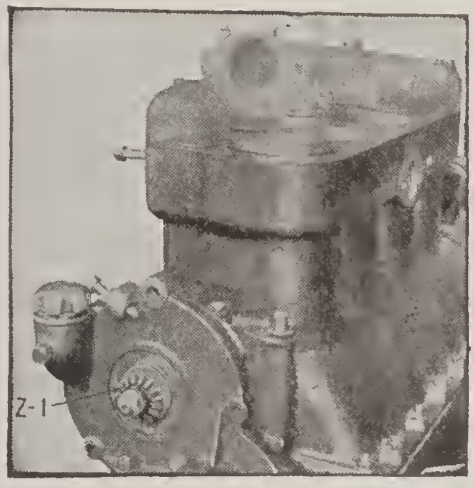


Fig. 440. First Step in Installing Westinghouse Ignition

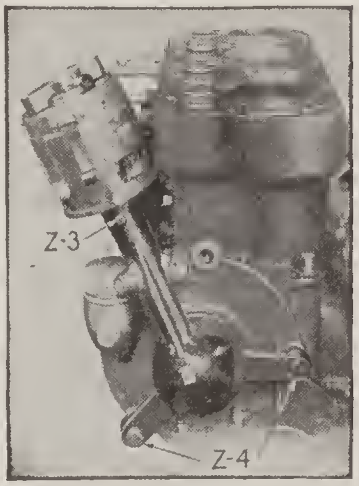


Fig. 441. View of Ignition Installation, Showing Timing Position

supporting bracket and put the holding screw in place. Be sure that the ignition unit turns freely in the bracket. Remove the distributor block and slide the ring cover up. Turn the entire unit until it is in the position shown in Fig. 441. Hold the unit firmly in this position

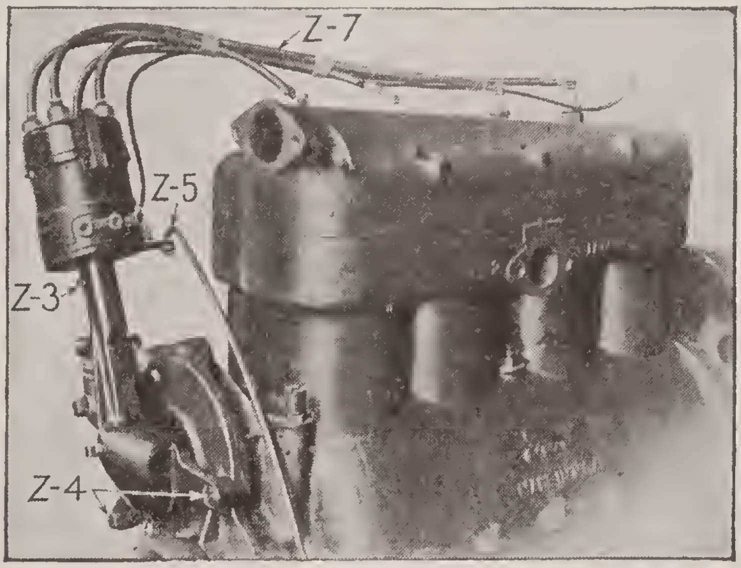


Fig. 442. Arrangement of Westinghouse Ignition Wiring

and turn the distributor brush arm counter-clockwise (to the left) until the contact brush is in the position shown in Fig. 441 and the interrupter contacts are just beginning to open. Clamp the unit in place on the engine exactly in this position. Use the two special screws *Z-4* to hold the bracket in place on the engine.

Connect the timer rod *Z-5*, furnished with the equipment, to the ignition unit, as shown in Fig. 442. Operate the spark lever on the steering post and see that the Westinghouse ignition unit follows the movement of the control lever. Mount the cover plate on the dash over the holes left by the Ford coil unit and cut a rectangular hole in the dash to receive the Westinghouse ignition switch. Fasten the cover plate and the ignition switch to the dash with the screws furnished for the purpose. Put the distributor block in place on the ignition unit and connect the wires to the spark plugs, as shown in Fig. 442. Be sure to connect each plug to the point shown in the diagram. Connect one end of the small wire *Z-7* to the terminal at the side and near the bottom of the ignition unit that has no other connection and connect the other end to the terminal on the ignition switch.

There are terminals provided for the purpose of reversing the current through the interrupter contacts; changing the short connection from one side to the other side and changing the primary wire reverses the current direction. Connect the terminal *B* on the switch to the negative side of the battery. This connection can be made most easily by using the terminal *B-1* on the starting switch, as shown in Figs. 437 and 438. The positive side of the battery is grounded. The engine may now be started in the usual way.

Operating Instructions. The Westinghouse-Ford system is a 12-volt single-unit single-wire type, the complete unit being permanently connected to the enginge by the silent-chain drive. The driving sprocket has a cushioned positive drive in the starting direction and a friction drive in the generating direction. This friction is adjustable for wear without removing any part of the equipment, as described later under Failure of Generator.

A battery cut-out, or magnetic switch, in the generator circuit serves to protect the battery; it cuts in when the engine attains a speed approximately equivalent to nine miles an hour on the direct drive. On low, it will naturally operate at a very much lower car speed as the engine is then running very much faster. If no lights are on, the battery begins to charge as soon as the cut-out operates; with lights burning, part of the current is diverted to them, but, at fifteen miles an hour or over, sufficient current is furnished to light all the lamps and charge the battery. The details of the cut-out, also of the starting switch, are shown in Fig. 443, while the method of

reassembling the carburetor choker, strangler, or priming device, as it is variously termed, with the new equipment provided, is shown in Fig. 444. In case the engine fails to start after the starting motor has operated five to ten seconds, the ring on the dash should be pulled as far as it will go and held there for a few seconds while the starting motor is operated again. Do not hold the ring down too long; if the

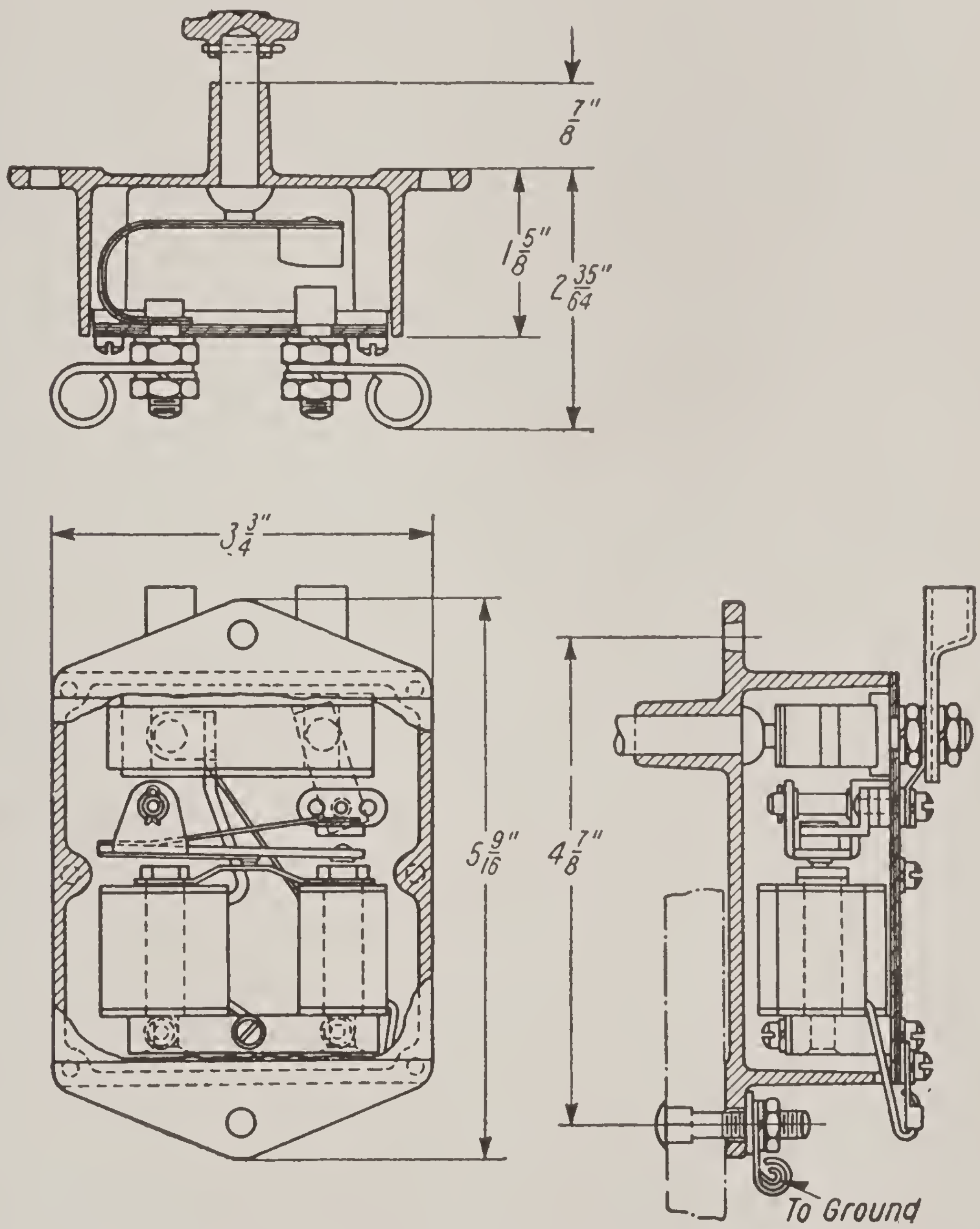


Fig. 443. Construction of Westinghouse Starting Switch and Cut-Out

engine does not start promptly with the carburetor choked, the failure must be caused by something else, and continuous running with the carburetor air inlet closed will quickly flood the engine with liquid gasoline.

Starting Troubles. If the electric motor fails to start when the switch is closed, open the switch and test out as follows, using a direct-current voltmeter: Connect voltmeter to give a reading of over 12

volts and test the battery. If the reading with the lamps on is 11 volts or less, the battery is practically exhausted. Instructions for keeping the battery in good condition will be found under its appropriate heading in the section on Storage Batteries. Trouble of this nature, particularly in cold weather, is frequently caused by not driving the car long enough between stops, so that the generator has no opportunity to charge the battery. Look for an open circuit, i.e., broken wire or loose terminal, in the wires *W*, *W-1*, and *W-2*, Figs. 437 and 438. Remove the spring collar over the brushes and see that they are in good condition, not sticky or gummed with oil and dirt, and are making good contact over their entire bearing surface on the commutator.

To Remove Brushes. Lift the spring that holds the brush in the guide and take out the screw holding the brush shunt, when the brush can be slipped out. In removing each brush, it should be noted which side was turned up, and each brush should be replaced in its original holder in the same way. In putting in new brushes, care should be taken to see that they have a good bearing fit over their entire surface on the commutator. To obtain this, they must be sanded-in (see Delco instructions). Only brushes supplied by the manufacturers of the system should ever be employed.

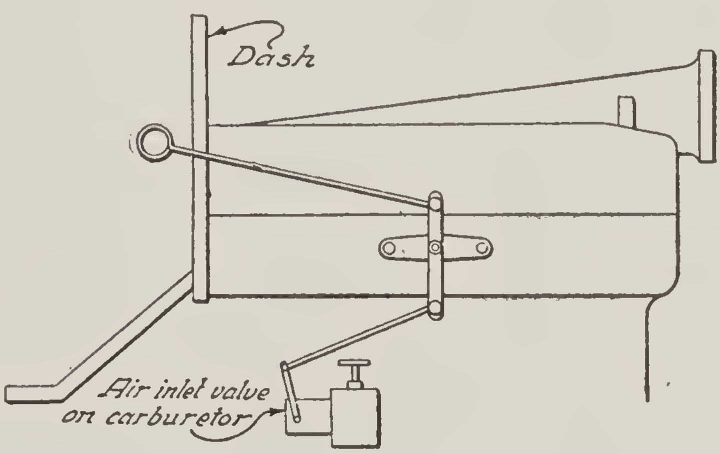


Fig. 444. Layout of Carburetor Strangler

Battery Does Not Stay Charged. If the car is not run for a sufficient length of time during the day or at a speed high enough to charge the battery, there may a ground in the wiring. With the engine idle and the lights off, disconnect the battery wire and touch it lightly on the terminal a few times. If a spark occurs, there is a ground in the wiring. The battery may not charge even at high speeds, owing to different causes. If there is a loose connection between the starting switch and the electric unit, see that the terminals hold the wire *W-2* tight and examine the wire between the terminals for breaks. The cut-out may not be operating properly. With the engine running, vary the speed and watch the contacts of the cut-out

to see that they connect the battery in the circuit at a speed above nine miles an hour and break the circuit again when the speed drops below this point. The cut-out contacts should be separated when the engine is not running, and they should remain closed as long as the engine runs above a certain speed. This cutting-in speed varies slightly. If the contacts do not close, there may be oil on the brushes or on the commutator; or one of the brushes may be worn too short; or one of the brush springs may be too loose.

Loose Friction Drive. If the commutator, the brushes, all the connections, and the wiring are in good condition, the trouble may be caused by the generator drive. To find out whether the friction sprocket has lost its tension or not, try to turn the electric unit by hand in both directions with the engine stationary. If it can be turned by hand easily in one direction, the nut *H-8* should be tightened sufficiently to enable the engine to drive the electric unit, Fig. 425. When running at 15 to 20 miles an hour, a faint click may be heard about every five minutes. If the clicking is more rapid than three or four times every five minutes, tighten the adjusting nut one-third to one-half turn.

The shunt-field brush *a* may not touch the commutator, Figs. 437 and 438. Adjust this brush, sanding it in, if necessary, and if this does not correct the trouble, test out the shunt-field circuit for open connections. This includes all circuits through the starting switch and the shunt-field winding. If the shunt-field winding is found to be open-circuited, the trouble was, no doubt, caused by an open circuit between the generator and the battery or by running the generator disconnected from the battery.

Lamps Do Not Light. If confined to a single lamp, this may be owing to the bulb having burned out, to an open circuit, or to a broken connection in the wiring. Should replacing with a new bulb not correct the trouble, test all the connections and the wiring and see that the lamp socket is grounded. When none of the lamps will light, test for a voltmeter reading with the lamps turned on but with the engine idle. If the voltmeter shows no reading, this may be owing to a broken connection at the battery or to the terminals having become so corroded as to amount to the same thing. The wire *W* may be disconnected or broken. If the voltmeter reading is correct, the trouble may be caused by a blown fuse. Should this be the case, do

not replace it immediately, but look over the wiring and the connections for an accidental ground or a short-circuit. In looking for grounds, hunt for abrasions of the insulation on the wire or for mechanical contacts between the ends of the cables or current-carrying parts of the wiring devices and the metal of the car, the socket, the shells, etc. When the trouble has been located and corrected, replace the blown fuse with another of the same type and capacity. If the trouble cannot be located immediately, turn off the switch on the damaged circuit and do not use until it can be remedied. Should the trouble be in a particular lamp socket, disconnect the attachment plug from this socket until the difficulty can be remedied and see that the removed attachment does not dangle against the metal of the car in such a way as to cause short-circuits.

All the lamps may be burned out. This is likely to happen when a battery wire breaks or becomes disconnected. It is also not unlikely that the battery may be entirely exhausted, though it will seldom get down to a point where the lamp filaments will not glow at least a dull red, without its condition having been detected. If the lamps become dim as soon as the engine stops, this indicates an exhausted battery, and if not convenient to drive the car to recharge it, the battery should be charged from an outside source. When the lamps flicker or go out momentarily, there is a loose connection, and the fact that all the lamps are thus affected indicates its location at the battery or in the wire *W-1*, Fig. 437. Should but one lamp be affected, only its particular circuit is at fault, and the trouble will usually be found in the socket itself, though a parted ground connection, which, owing to the vibration, will sometimes touch and at other times be shaken away from its contact, may be responsible. As a 6-cell battery is supplied, 14-volt lamps must be used.

Operation of Ignition Unit. The vertical ignition unit of the Westinghouse type is composed of four essential units, viz, the interrupter, or contact-breaker; the induction coil; the distributor; and the condenser. The operation of the interrupter may be observed by lossening the thumb screw *E* and sliding upward the loose section of the insulating housing which forms the interrupter cover, Fig. 445. With the ignition switch "On" and the engine running, each segment of the interrupter cam, in turn, passes on and off the fiber bumper, Fig. 445. As each cam passes off the bumper, the interrupter contacts

close, closing the circuit from the battery to the primary winding of the coil. Then, as they are lifted by the bumper, the contacts are separated, suddenly opening the circuit and inducing a high-tension current in the secondary of the induction coil. This current is directed by the distributor on top of the ignition unit to the proper spark plug. The ignition switch is a simple, single-pole type connecting

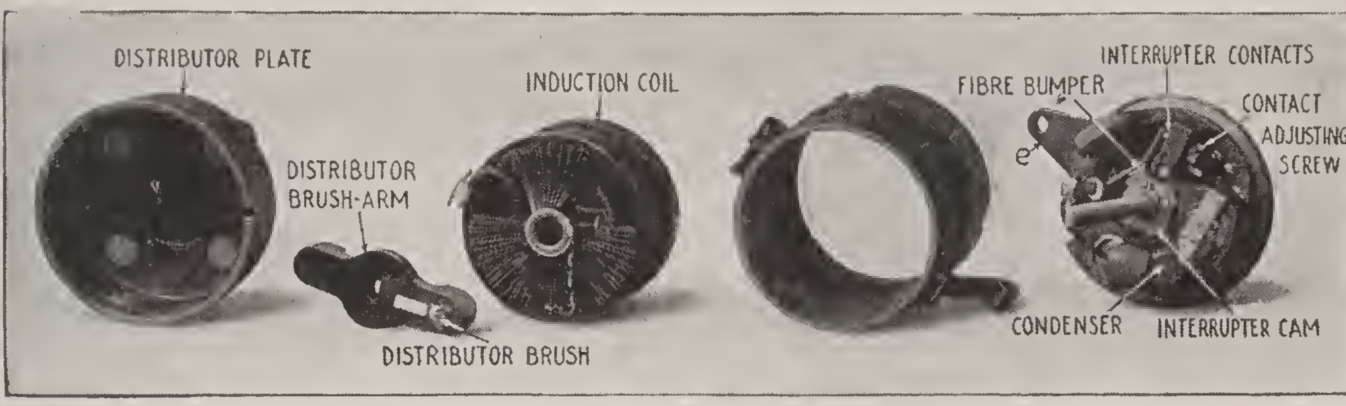


Fig. 445. Parts of Westinghouse Ignition Unit

the negative side of the battery to the ignition terminal, Fig. 446. This switch is a reversing type, i.e., it changes the direction in which the current passes through the interrupter contacts each time it is operated. Particular attention is directed to the rear view of the switch. As received, this switch does not operate to reverse the current direction. If it be desired to utilize this feature, remove the

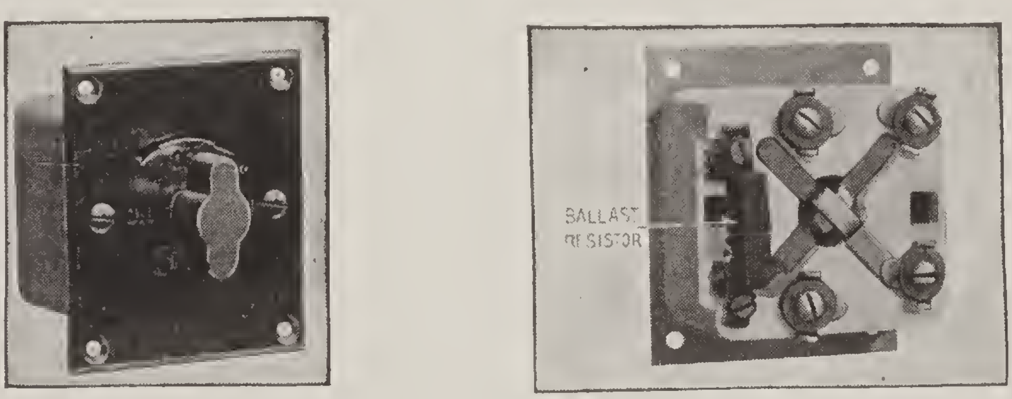


Fig. 446. Front and Back Views of Westinghouse Ignition Switch

metal strip that connects two of the three terminals on the ignition unit. Also remove the metal strip that connects two of the four switch terminals. Connect the terminal on the switch to the center terminal on the ignition unit. Obtain two extra wires, like the one supplied to connect the switch and the ignition unit, and connect the two switch terminals to the two outside terminals on the ignition unit.

Ballast Resistor. This is a resistance unit which will be noted mounted on the rear face of the switch, Fig. 446. It is connected in series with the primary ignition circuit and is an important part of the ignition system, its function being to protect both the ignition system and the battery. In case this resistance unit should become broken or inoperative from any cause, a standard 5-ampere fuse may be used in an emergency, *but a fuse of more than 5-ampere capacity must never be employed in any case.* Unless absolutely necessary to do so in order to run the car, the ignition system should never be operated without the ballast resistor, as serious injury is likely to result. A very fine piece of wire, such as a single strand of lamp cord, should be used for bridging the gap.

ELECTRIC GEAR=SHIFT

General Plan. One of the more recent additions to the electrical equipment of the automobile that the installation of a generator and a constantly charged storage battery on the car has made possible is the electric gear-shift. While it has not yet been extensively adopted, it is already in use on a number of cars and is slowly coming into favor, and from now on the garage man will find more machines thus fitted coming into his hands and will be called upon to give attention to this as well as to the other parts of their electrical equipment.

In the standard three-speed and reverse gear of the selective type, four movements are necessary to engage all the speeds. These changes in the relations of the gears are carried out by means of a sliding pinion for first and second speeds, a toothed clutch for direct drive, and the interposition of an idler between two of the driving gears to give the reverse; all these movements being accomplished by means of a yoke on the member to be moved. This yoke is mounted on a movable rod, or bar, which is, in turn, connected through convenient linkage to the hand lever. In the electrically operated gear, all these parts, with the exception of the hand lever, which is dispensed with, remain the same and their functions are unaltered. The bars on which the yokes are mounted, two in number, Fig. 447, are lengthened somewhat, and their extended ends form armatures, or cores, for four solenoids.

Principle of Action. As has been explained in the introductory in connection with electromagnetism, passing a current through a

solenoid will cause it to draw its core into the coil. This is the principle on which the electric gear-shift operates. There is a solenoid for each movement necessary. For example, to obtain first speed, the bar *A*, which carries the yoke attached to the sliding gear (not shown), must be moved to the left, Fig. 447. To accomplish this, button *1* is pressed. This closes the circuit through the solenoid *1*, but no current flows through its winding until the master switch controlling the current supply to all the solenoids is closed. The master switch is operated by pushing the clutch pedal forward, exactly as when shifting a gear by hand. This energizes solenoid *1*, the bar *A* moves to the left, carrying the sliding pinion with it by means of the usual yoke, and the first-speed gear is engaged. The operation throughout is the same. A neutralizing device, described later, opens the master switch and cuts off the current. The speed desired is selected by pushing the numbered button under the steering wheel, the clutch is disengaged momentarily by pushing the pedal all the way forward when the change is desired, and the gears shift automatically. Thus the solenoid *2* moves the bar *A* to the right to give second, or intermediate, speed; solenoid *3* moves the bar *B* to the left to give the direct drive, or high speed; while *R* moves the same bar to the left to give the reverse engagement.

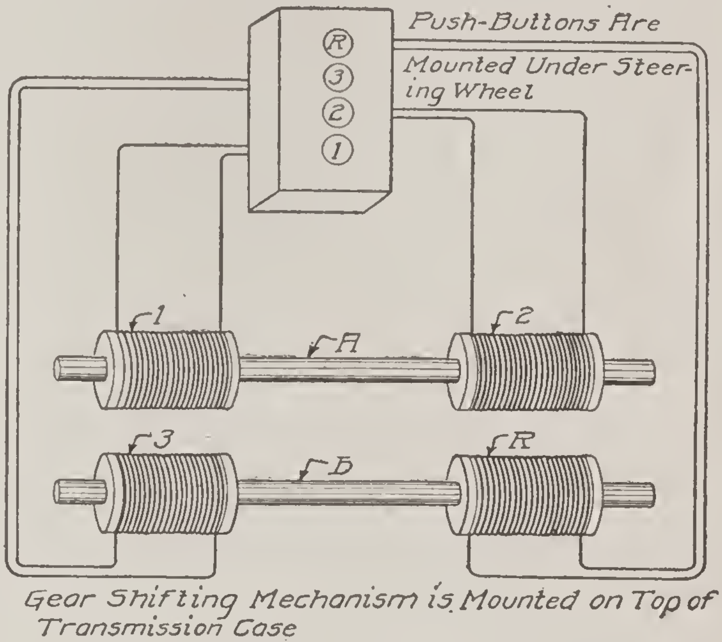


Fig. 447. Diagram Showing Principle of Electric Gear-Shift
Courtesy of Cutler-Hammer Manufacturing Company, Milwaukee, Wisconsin

The buttons on the steering post, when pressed do not entirely close the circuit but merely place the particular solenoid which they control in connection with the master switch. They are known as "selector switches". They select in advance the circuit which will be energized when the master switch is closed. To do this, the clutch pedal must be depressed all the way, in order to permit de-clutching without bringing this switch into action, that is, when the clutch pedal is depressed only part way, as in cutting off the power, no contact is made at the master switch.

Stopping the Car. When it is desired to stop the car, the clutch pedal is depressed all the way, after the neutral button has been pressed. Pressing this button breaks any contacts that may have been made previously by the selector switch buttons, and depressing the clutch pedal then brings into action what is termed the neutralizing device. For example, the car has been running on high, the neutral button is pressed and the clutch pedal pushed all the way forward. This causes the operating lever *K* to move ahead, Fig. 448. Then the neutralizing cams *F* pull on the boss on the shifter forks as if a shift were to be made, and the master switch *M* will also close; but, as the neutral button has opened all the selector switches,

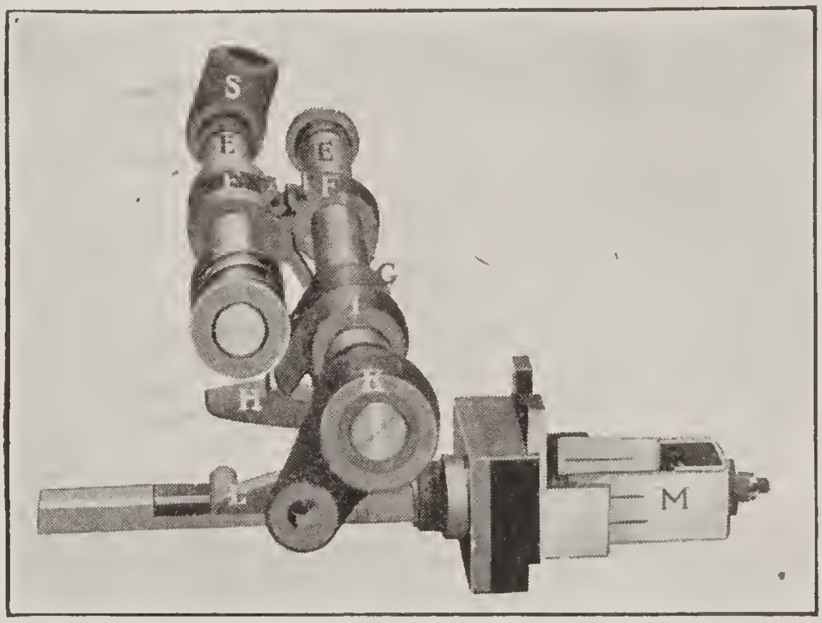


Fig. 448. End View of C-H Neutralizing Mechanism and Master Switch
Courtesy of Cuttler-Hammer Manufacturing Company, Milwaukee, Wisconsin

no current flows, and as the solenoids are not energized, the gears remain in neutral. Fig. 449 shows a plan view of the neutralizing mechanism and the master switch, while Fig. 450 illustrates the solenoids (two of them) and their mounting in detail. The relative locations of these solenoids to the remainder of the operating mechanism is shown by the phantom view of the complete gear box, Fig. 451. The solenoids are identified by the letters *B1, 2,* etc., and their cores by the letters *C1, 2,* etc. A complete wiring diagram is given in Fig. 452.

Starting First Speed. Assuming that the gears are in neutral and it is desired to start, then first-speed button of the selector switch on the steering wheel is pressed, partly closing the circuit of one of

the magnets. Depressing the clutch pedal all the way rotates the lever K through the connecting rod L which is linked to the clutch

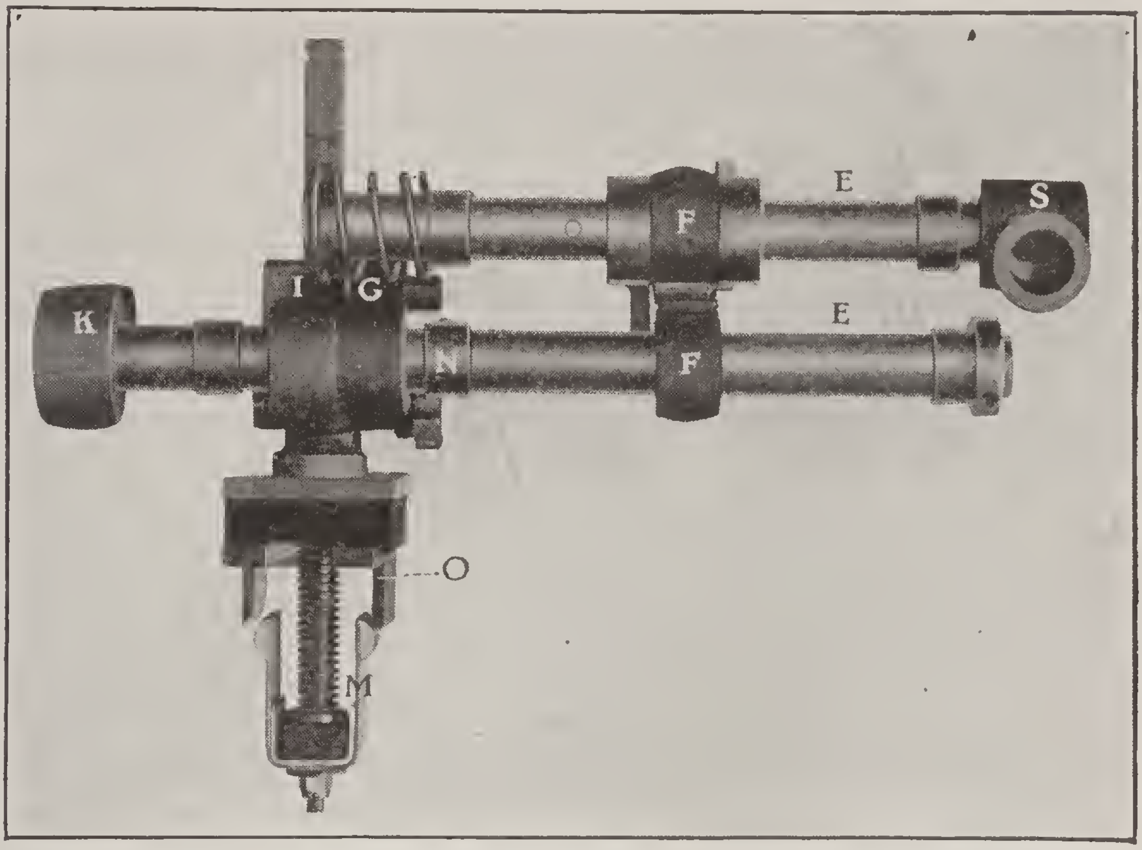


Fig. 449. Plan View of C-H Neutralizing Mechanism and Master Switch
Courtesy of Cutler-Hammer Manufacturing Company, Milwaukee, Wisconsin

pedal. This pulls the blades of the master switch M into contact, completing the circuit and energizing the solenoid. As the gears engage,

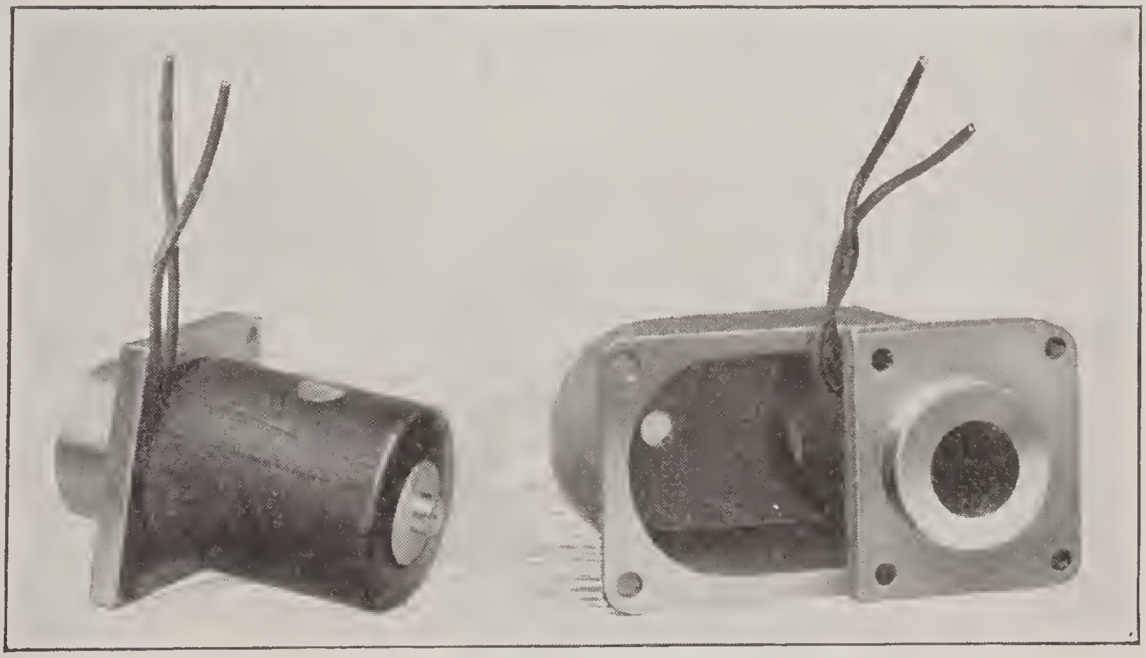


Fig. 450. View of Magnet Case and Electric Solenoids
Courtesy of Cutler-Hammer Manufacturing Company, Milwaukee, Wisconsin

and the sliding member is within $\frac{1}{2}$ inch of being "home", the pawl G, Fig. 448, falls back, owing to the pull of the magnet against the

neutralizing cams F, causing it to strike against the trigger N, which is attached to the switch-operating pawl L. This action causes the pawl L to be raised out of engagement with the stem of the master

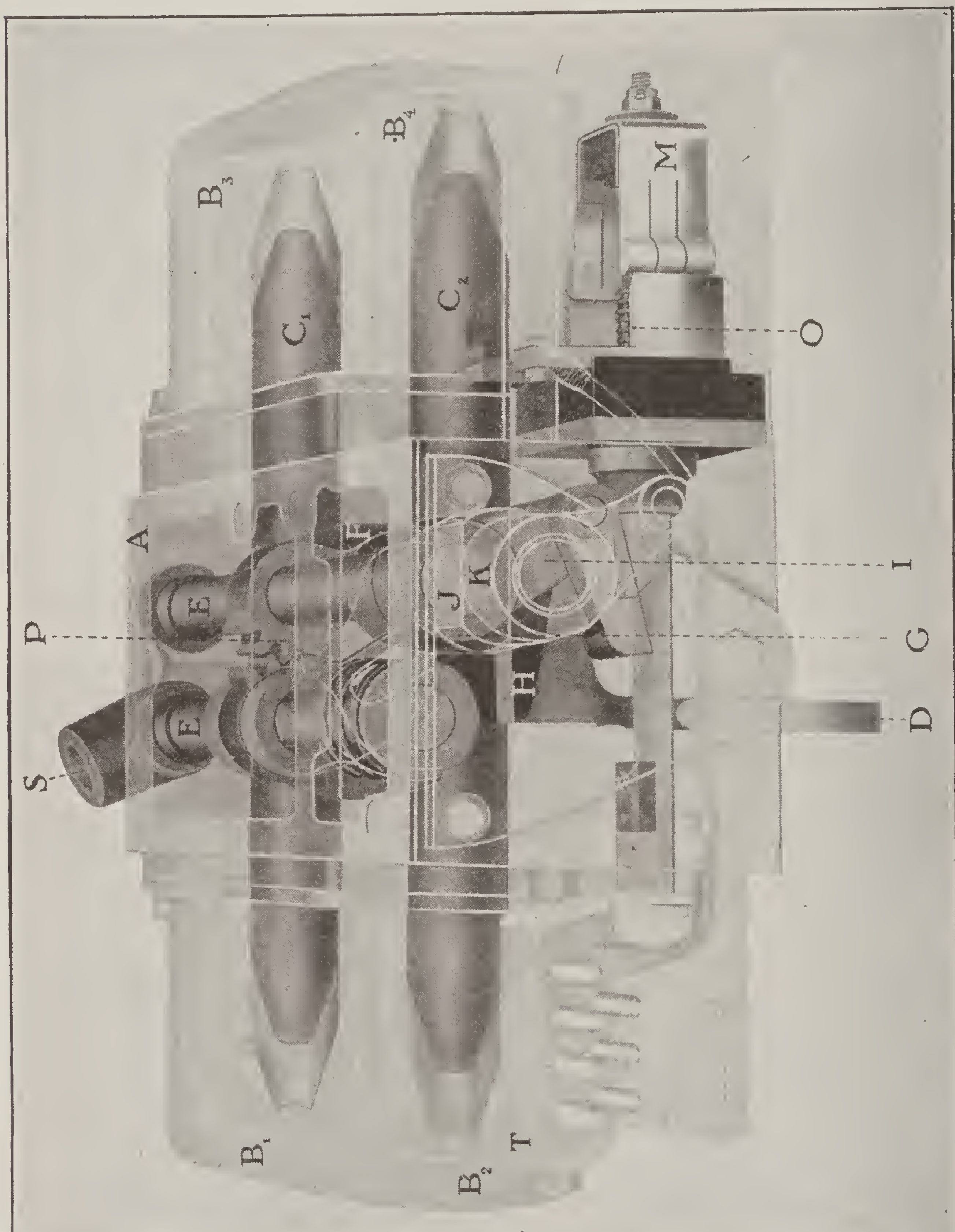


Fig. 451. Phantom View of C-H Gear-Shifting Arrangement
Courtesy of Cutler-Hammer Manufacturing Company, Milwaukee, Wisconsin

switch, and the latter snaps open instantly, owing to the pull of the spring O, Fig. 449. The actual time of engagement, during which current is being drawn from the battery, is said to be less than one-third of a second.

From First to Intermediate or High. Being in first speed and desiring to shift, the button corresponding to the speed desired, i.e., either intermediate or high, is pressed at the convenience of the driver. When it is desired to make the change, the clutch pedal is pushed all the way forward, this action rotating the operating lever

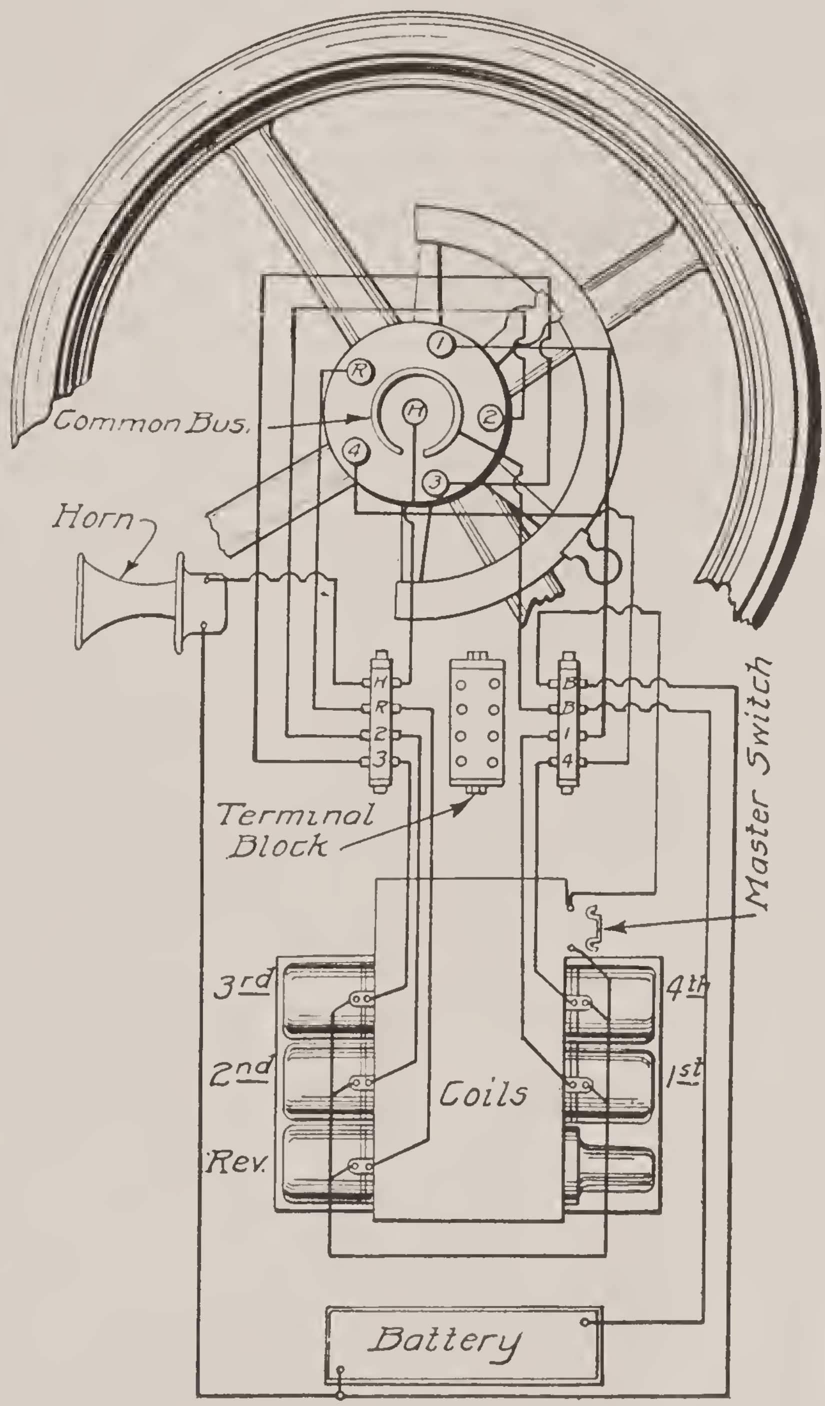


Fig. 452. Complete Wiring Diagram for C-H Electric Gear-Shift

K and its shaft which carries the rocker arm *I* and its attached mechanism. As the first gear, or whichever gear has been previously operated, is still in mesh, the latch *H* is in engagement with the pawl *G* of the neutralizing mechanism, and, as the operating lever and the rocker arm *I* are rotated, the latch *H* presses against the pawl *G*, causing both of the neutralizing cams *F* to rotate toward the center,

owing to their being engaged through the teeth *P*. On the central side of the shifter forks *D*, Fig. 451, there is a boss, and as the neutralizing cams *F* rotate, they press against the boss on whichever side is in engagement. This mechanically pulls the shifter fork and the gear with which it is engaged back to the neutral position before the next shift can be made. As the gear reaches the neutral position, the end of the latch *H* strikes the knockout pin. This action releases the latch from engagement with the pawl *G*, and as the operating lever *K* is moved ahead by the driver's foot on the clutch pedal, the switch operating pawl *L* pulls against the switch stem, closing the circuit at the master switch. This action is the same for all speeds in the gear box. In case of failure of the current through exhaustion of the battery or other cause, an emergency hand lever may be inserted in the socket *S* and the gears may be changed in the usual manner by hand.

Wiring. Referring to the wiring diagram, Fig. 452, it will be noted that the wiring is very simple. To permit the removal of the gear box, if necessary, without having to disconnect any permanently fastened cables, all the wires are led to a terminal block, the actual location of which is shown on the gear box, Fig. 451. Connections at this terminal block are simplified by making each terminal a different size so that the wires can be replaced only on the terminals which correspond to them. There is, accordingly, no risk of confusing them. A single wire leads from each magnet coil through the terminal block to its particular speed button on the selector switch, while the other lead from the coil is connected to a neutral wire directly through the terminal block and the master switch to the battery. Another wire from the battery passes through the terminal block to the contact of the selector switch which is common to all speeds. The circuit is accordingly from the positive terminal of the battery through the depressed push button on the selector switch, through the winding of the coil to which the button in question corresponds, and back through the master switch to the other terminal of the battery.

Operating Troubles. A failure on the part of the gear box to shift electrically would be likely to occur, after considerable usage, in about the following order:

(1) A break in the linkage connecting *L* with the clutch pedal, which would prevent the neutralizing mechanism from coming into operation, and would also prevent the master switch from closing.

(2) Dirt or wear which would prevent the fingers of the master switch from making proper contact; failure of the spring *O*, of the master switch, through breakage, so that the master switch would not open automatically immediately upon completing the shifting of the gears, as is normally the case.

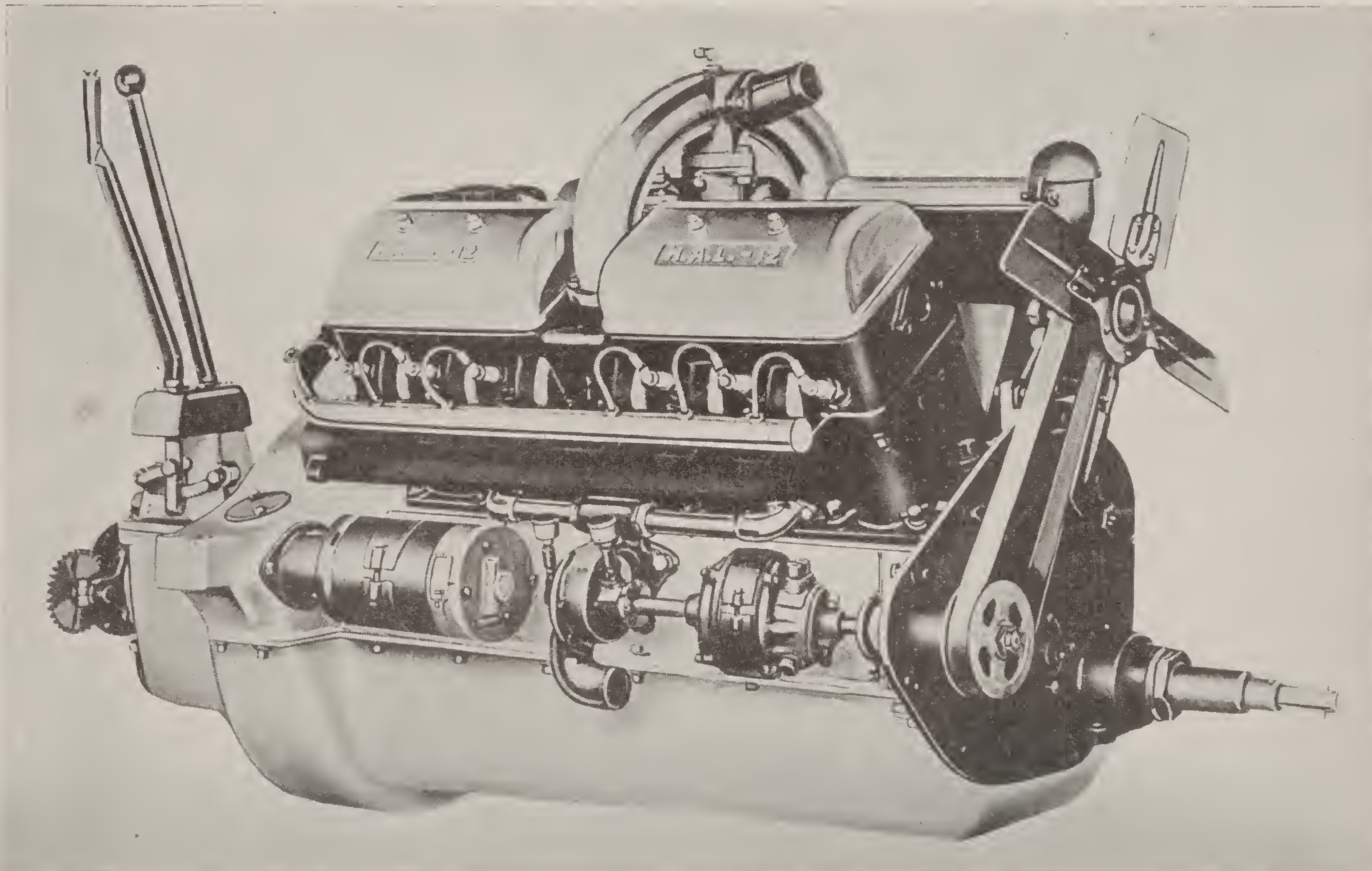
(3) Excessive jolting and vibration causing some of the leads to shake loose from the terminal block.

(4) Breakage or loosening of some of the connections at the selector switch owing to the same cause. (The wiring itself is so well protected that any injury to it is remote.)

(5) Jamming of the solenoid cores in the brass tubes in which they slide in the coils, owing to the shaft getting out of alignment. To operate properly, it should be easy to move the entire shifting mechanism by hand with very little effort.

(6) Exhausted storage battery which, as a matter of fact, should always be tested first, but which, like the empty gasoline tank, is such patent cause of failure that it seems almost unnecessary to mention it, either first or last. As is pointed out at considerable length under the appropriate heading, there are numerous causes for the exhaustion of the battery, so that its condition should always be inspected before attempting to investigate the shifting mechanism.

Should an examination prove the battery to be sufficiently charged, the electric test-lamp set—described in connection with trouble hunting in the starting and lighting systems—will prove a valuable aid in running down the open circuit or the short-circuit that is preventing the gear box from operating. Test the circuit of each solenoid in turn; inspect the connections of the master switch and the condition of its contact fingers, also the connections at the terminal block and at the selector switch. The test lamp should quickly reveal just which circuit is at fault.



WESTINGHOUSE STARTING AND LIGHTING SYSTEM AS DESIGNED FOR H.A.L. TWELVES
Courtesy of Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART VIII

ELECTRIC STARTING AND LIGHTING SYSTEMS—(Continued)

STARTING AND LIGHTING STORAGE BATTERIES

Importance of the Battery in Starting and Lighting. In the last analysis, every electric lighting and starting system on the automobile is necessarily a battery system. An electric starter is, first and last, a battery starter, since no system can be any more powerful than its source of energy. In other words, the storage battery is the business end of every electrical starting and lighting system. Just as the most elaborate and reliable ignition apparatus is of doubtful value with poor spark plugs, so the finest generators, motors, and auxiliaries become useless if the battery is not in proper working order.

Storage Battery Requires Careful Attention. A little experience in the maintenance of electric starting and lighting systems will demonstrate very forcibly that the relative importance of the storage battery is totally disproportionate to that of all the remaining elements of the system put together. The latter essentials have been perfected to a point where they will operate efficiently without attention for long periods. The battery, on the other hand, requires a certain amount of attention at regular and comparatively short intervals. Usually, this attention is not forthcoming, or it may be applied at irregular intervals and with but scant knowledge of the underlying reasons that make it necessary. Consequently, the battery suffers. It is abused more than any other single part of the entire system and, not being so constituted that it can withstand the effects of this abuse and still operate efficiently, it suffers correspondingly. Then the entire system is condemned.

Other things being equal, the successful operation of any starting and lighting system centers almost wholly in the proper maintenance of the storage battery. Not all the defections that this part of the electrical equipment of the car suffers are caused by the battery, but unless properly cared for, it will be responsible for such a large proportion that the shortcomings of the rest of the system will be entirely forgotten. To make it even stronger, it may well be said that unless the storage battery is kept in good condition, the rest of the system will not have an opportunity to run long enough to suffer from wear. In a great many cases that come to the repair man's attention, the battery is ruined in the first six months' service, usually through neglect. For this reason, considerable attention is devoted to the battery and its care in this connection, despite the fact that it is very fully covered in the volume on Electric Vehicles. The conditions of operation, however, are totally unlike in the two cases. In one instance, the energy of the battery is called for only at a rate of discharge which is moderate by comparison with the ampere-hour capacity, while the battery itself is constantly under the care of a skilled attendant. In the other instance, the demand for current is not alone excessive but wholly disproportionate to the total capacity of the battery when it is used for starting, and intelligent care is usually conspicuous by its absence.

PRINCIPLES AND CONSTRUCTION

Function of Storage Battery. In the sense in which it is commonly understood, a battery does not actually store a charge of electricity. The process is entirely one of chemical action and reaction. A battery is divided into units termed *cells*. Each cell is complete in itself and is uniform with every other cell in the battery, and one of the chief objects of the care outlined subsequently is to maintain this uniformity. Each cell consists of certain elements which, when a current of electricity of a given value is sent through them in one direction for a certain length of time, will produce a current of electricity in the opposite direction if the terminals of the battery are connected to a motor, lamps, or other resistance. The cell will, of course, also produce a current if its terminals are simply brought together without any outside resistance. This, however, would represent a *dead short-circuit* and would permit the battery to dis-

charge itself so rapidly as to ruin its elements. This is one of the things that must be carefully guarded against. When attending a battery, see that its terminals are not left exposed where tools may accidentally drop on them. When the current is being sent into the battery, as mentioned above, it is said to be charging; when it is connected to an outside resistance, it is discharging.

Parts of Cell. *Elements.* These are known as the positive and negative plates and correspond to the positive and negative electrodes of a primary battery. They consist of a foundation composed of a casting of metallic lead in the form of a grid, the outer edges and the connecting lug being of solid lead, while the remainder of the grid is like two sections of lattice work so placed that the openings do not correspond. Every manufacturer has different patterns of grids, but this description will apply equally well to all of them. Fig. 453 illustrates the grid of the Philadelphia battery. The object in giving them this form is to make the active material of the plates most accessible to the electrolyte, or solution, of the battery, and at the same time to insure retaining this active material between the sides of the grid.

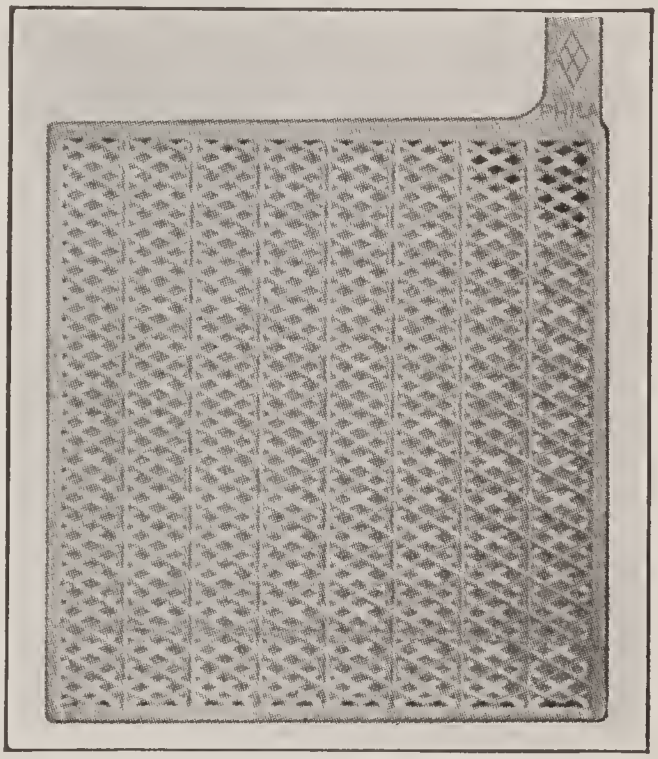


Fig. 453. Lead Grid Ready for Active Material
Courtesy of Philadelphia Storage Battery Company, Philadelphia, Pennsylvania

This active material consists of peroxide of lead (red lead) in the positive plate and litharge, or spongy metallic lead, in the negative plate. The plates are said to be pasted, to distinguish them from the old-style plates which were "formed" by a number of charges and discharges. The active material is forced into the interstices of the grid under heavy pressure, so that when completed the plate is as hard and smooth as a piece of planed oak plank. The positive plate may be distinguished by its reddish color, while the negative is a dark gray. Each positive plate faces a negative in the cell, and as the capacity of the cell is determined by the area

of the positive plates, there is always one more negative plate than positive plates in a cell. The lead connectors of each of the plates is burned to its neighbor of the same kind, thus forming the positive and negative groups which constitute the elements of the cell.

Separators. As the elements must not be allowed to come in contact with each other in the cell because to do so would cause an internal short-circuit to which reference is made later, and as the maximum capacity must be obtained in the minimum space, the plates are placed very close together with wood and perforated hard rubber separators between them. These are designed to fit very snugly, so that the combined group of positive and negative plates is a very compact unit. When reassembling a cell, it is important that these separators be properly cared for in accordance with the directions given later.

Electrolyte. To complete the cell, the grouped elements with their separators are immersed in a jar holding the electrolyte. This is a solution consisting of water and sulphuric acid in certain proportions, both the acid and the water being chemically pure to a certain standard. This is the grade of acid sold by manufacturers as battery acid and in drug stores as C.P. (chemically pure), while the water should be either distilled, be cleanly caught rain water, or melted artificial ice. In this connection, the expression "chemically pure" acid is sometimes erroneously used simply to indicate acid of full strength, i. e., undiluted, as used in the cells in the form of electrolyte. It will be apparent that whether at its original strength or diluted with distilled water, it is still chemically pure. In mixing electrolyte, a glass, porcelain, or earthenware vessel must be used and *the acid must always be poured into the water.* Never attempt to pour the water into the acid, but always add the acid, a little at a time, to the water. The addition of the acid to the water does not make simply a mechanical mixture of the two but creates a solution in the formation of which a considerable amount of heat is liberated. Consequently, if the acid be poured into the water too fast, the containing vessel may be broken by the heat. For the same reason, if the water be poured into the acid, the chemical reaction will be very violent, and the acid itself will be spattered about. Sulphuric acid is highly corrosive; it will cause painful burns whenever it comes in contact (even in dilute solution) with the skin and will

quickly destroy any fabric or metal on which it falls. It will also attack wood, for which reason nothing but glass, earthenware, or hard rubber containers should be employed.

Specific Gravity. The weight of a liquid as compared with distilled water is known as its specific gravity. Distilled water at 60° F. is 1, or unity. Liquids heavier than distilled water have a specific gravity greater than unity; lighter liquids, such as gasoline, have a specific gravity less than that of distilled water. Concentrated sulphuric acid (battery acid, as received from the manufacturer) is a heavy oily liquid having a specific gravity of about 1.835. A battery will not operate properly on acid of full strength, and it is therefore diluted with sufficient water to bring it down to 1.275. This, however, is the specific gravity of the electrolyte only when the battery is fully charged. The specific gravity of the electrolyte affords the most certain indication of the condition of the battery at any time, and its importance in this connection is outlined at considerable length under the head of Hydrometer Tests. The following table shows the parts of water by volume, the parts of water by weight, and the percentage of acid to water to produce electrolyte of different specific gravities.

Action of Cell on Charge. When the elements described are immersed in a jar of electrolyte of the proper specific gravity, and terminals are provided for connecting to the outside circuit, the cell is complete. As the lead-plate storage battery produces current at a potential of but two volts per cell, however, a single cell is rarely used. The lowest number of cells in practical use is the three-cell unit of the 6-volt battery used for starting and lighting on the automobile. The different cells of the battery are usually permanently connected together by heavy lead straps, while detachable terminals are provided for connecting the battery to an outside circuit. When the charging current is sent through the cell, the action is as follows: The original storage-battery cell of Planté consisted simply of two plates of lead; when the current was sent through such a cell on charge, peroxide of lead was deposited on the positive plate and spongy metallic lead on the negative. This was termed "forming" the plate. By modern methods of manufacture, this active material is formed into a paste with dilute sulphuric acid, and is pressed into the grids. On being charged, this acid is forced

out of the plates into the electrolyte, thus raising the specific gravity of the electrolyte. When practically all of this acid has been transferred from the active material of the plates to the solution, or electrolyte, the cell is said to be fully charged and should then show a specific gravity reading of 1.275 to 1.300. The foregoing refers of course to the initial charge. After the cell has once been discharged, the active material of both groups of plates has been converted into lead sulphate. The action on charge then consists of driving the acid out of the plates and at the same time reconverting the lead sulphate into peroxide of lead in the positive plates and into spongy metallic lead in the negative plates.

Action of Cell on Discharge. The action of the cell on discharge consists of a reversal of the process just described. The acid which has been forced out of the plates into the electrolyte by the charging current again combines with the active material of the plates, when the cell is connected for discharge to produce a current. When the sulphuric acid in the electrolyte combines with the lead of the active material, a new compound, lead sulphate, is formed at both plates. This lead sulphate is formed in the same way that sulphuric acid, dropped on the copper-wire terminals, forms copper sulphate, or dropped on the iron work of the car, forms iron sulphate. In cases of this kind, it will always be noted that the amount of sulphate formed is all out of proportion to the quantity of metal eaten away. In the same manner, when the sulphuric acid of the electrolyte combines with the lead in the plates to form lead sulphate, the volume is such as to completely fill the pores of the active material when the cell is entirely discharged. This makes it difficult for the charging current to reach all parts of the active material and accounts for the manufacturers' instructions, never to discharge the battery below a certain point.

As the discharge progresses, the electrolyte becomes weaker by the amount of acid that is absorbed by the active material of the plates in the formation of lead sulphate, which is a compound of acid and lead. This lead sulphate continues to increase in bulk, filling the pores of the plates, and as these pores are stopped up by the sulphate, the free circulation of the acid is retarded. Since the acid cannot reach the active material of the plates fast enough to maintain the normal action, the battery becomes less active,

which is indicated by a rapid falling off in the voltage. Starting at slightly over 2 volts per cell when fully charged, this voltage will be maintained at normal discharge rates with but a slight drop, until the lead sulphate begins to fill the plates. As this occurs, the voltage gradually drops to 1.8 volts per cell and from that point on will drop very rapidly. A voltage of 1.7 volts per cell indicates practically complete discharge, or that the plates of the cell are filled with lead sulphate and that the battery should be placed on charge immediately.

During the normal discharge, the amount of acid used from the electrolyte will cause the specific gravity of the solution to drop 100 to 150 points, so that if the hydrometer showed a reading of 1.280 when the cell was fully charged, it will indicate but 1.130 to 1.180 when it is exhausted, or completely discharged. The electrolyte is then very weak; in fact, it is little more than pure water. Practically all of the available acid has been combined with the active material of the plates. While the acid and the lead combine with each other in difinite proportions in producing the current on discharge, it is naturally not possible to provide them in such quantities that both are wholly exhausted when the cell is fully discharged. Toward the end of the discharge, the electrolyte becomes so weak that it is no longer capable of producing current at a rate sufficient for any practical purpose. For this reason, an amount of acid in excess of that actually used in the plates during discharge is provided. This is likewise true of the active material.

Capacity of a Battery. The amount of current that a cell will produce on discharge is known as its capacity and is measured in ampere hours. It is impossible to discharge from the cell as much current as was needed to charge it, the efficiency of the average cell of modern type when in good condition being 80 to 85 per cent, or possibly a little higher when at its best, i.e., after five or six discharges. In other words, if 100 ampere hours are required to charge a battery, only 80 to 85 ampere hours can be discharged from it. This ampere-hour capacity of the cell depends upon the type of plate used, the area of the plate, and the number of plates in the cell, i.e., total positive-plate area opposed to total negative-plate area. To accomplish this, both outside plates in a cell are made negative. The ampere-hour capacity of a battery, all the

cells of which are connected up as a single series, is the same as that of any single cell in the series; as in connecting up dry cells in series, the current output is always that of a single cell, while the voltage of the current increases volts for each cell added to the series. In the case of the storage battery, it increases two volts for each cell.

The capacity of the cell as thus expressed in ampere hours is based on its normal discharge rate or on a lower rate. For example, take a 100-ampere-hour battery. Such a battery will produce current at the rate of 1 ampere for practically 100 hours, 2 amperes for 50 hours, or 5 amperes for 20 hours; but as the discharge rate is increased beyond a certain point, the capacity of the battery falls off. The battery in question would not produce 50 amperes of current for 2 hours. This is because of the fact that the heavy discharge produces lead sulphate so rapidly and in such large quantities that it quickly fills the pores of the active material and prevents further access of the acid to it. Thus, while it will not produce 50 amperes of current for 2 hours on continuous discharge, it will be capable of a discharge as great or greater than this by considerable, if allowed periods of rest between. When on open circuit, the storage battery recuperates very rapidly. It is for this reason that when trying to start the switch should never be kept closed for more than a few seconds at a time. Ten trials of 10 seconds each with a half-minute interval between them will exhaust the battery less than will spinning the motor steadily for a minute and forty seconds.

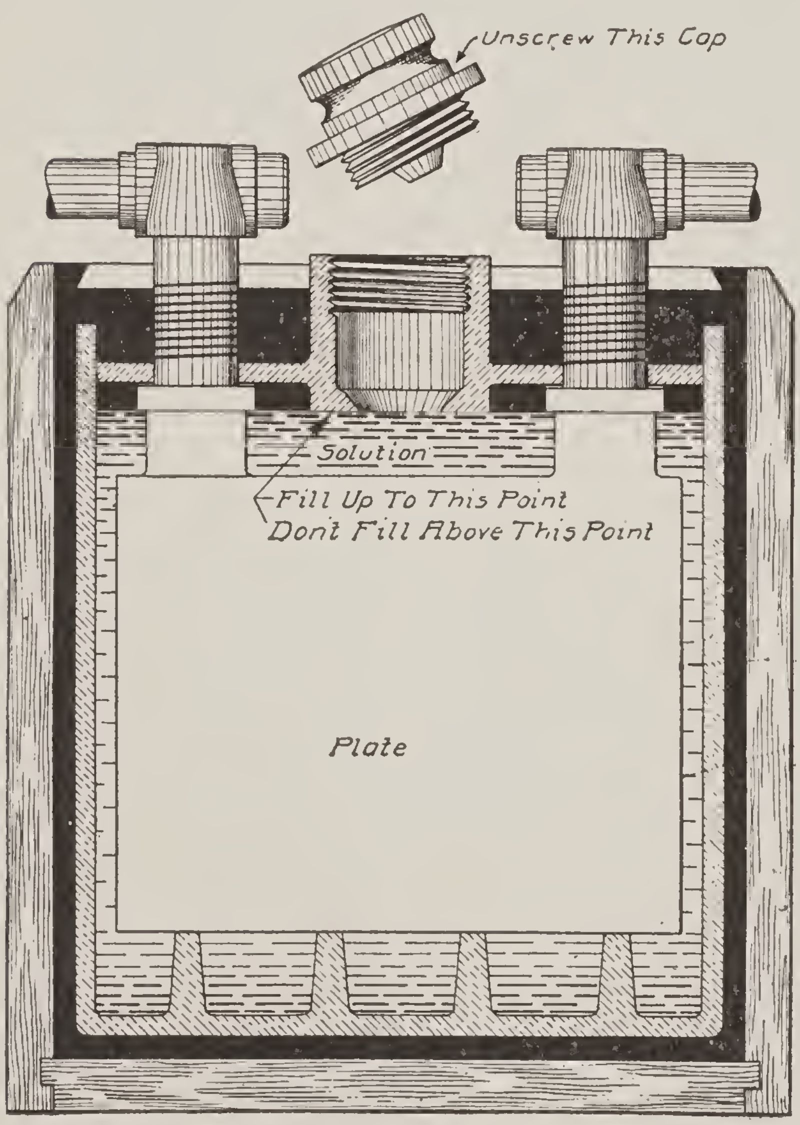


Fig. 454. Section of Willard Starting Battery, Showing Mud Space

Construction Details. For automobile starting and lighting service, the elements of the cells are placed in insulating supports in the bottom of the hard rubber jars and sealed in place. These supports hold the plates off the bottom of the jar several inches in the later types of starting batteries. Figs. 454 and 455 show sections of the Willard starter battery and another standard type This is known as the mud space and is designed to receive the accumulation of sediment consisting of the active material which is shaken off the plates in service. This active material is naturally a good electrical conductor, and if it were allowed to come in contact with the bottoms of the groups of plates, it would short-circuit the cell. Sufficient space is usually allowed under the plates to accommodate practically all of the active material that can be shed by the plates during the active life of the cell. In a battery having cells of this type, it is never necessary to wash the cells, as the elements themselves would require renewal before the sediment could reach the bottom of the plates.

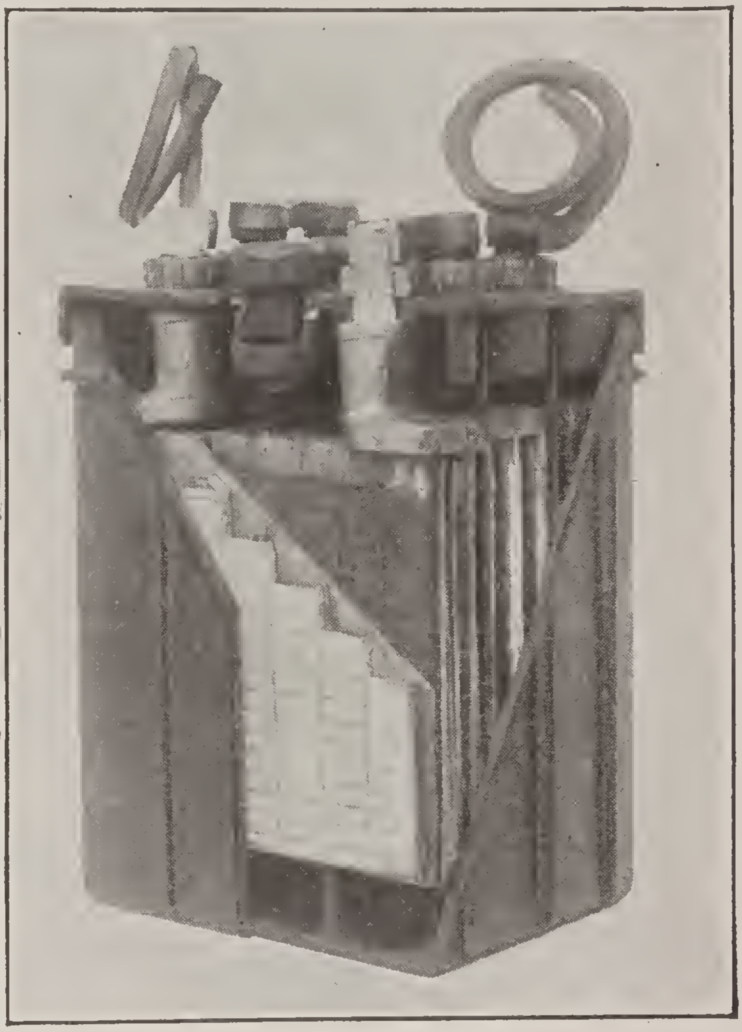


Fig. 455. Typical Starting Battery with Plates Cut Down, Showing Assembly

In sealing the elements into the jar, a small opening is left for the purpose of adding distilled water as well as to permit the escape of the gas when the battery is charging. Except when being used for refilling the jars, this opening is closed by a soft rubber stopper which has a small perforation through which the hydrogen passes out of the cell when the latter is gassing, as explained later. The different cells of a battery are electrically connected by heavy lead straps, these strips being usually burned onto the plates by the lead-burning process.

Edison Cell Not Available. It will be noted that the foregoing description has been confined entirely to the lead-plate type of storage battery and that no mention has been made of the Edison cell. The latter is not available for starting service on the automobile, because its internal resistance is too high to permit the extremely heavy discharge rate that is necessary. In extremely cold weather or where the engine is unusually stiff for other reasons, this may be as high as 300 amperes momentarily, while, under ordinary conditions, it will reach 150 to 200 amperes at the moment of closing the switch. The efficiency of the Edison cell also drops off very markedly in cold weather, though this is also true to a lesser extent of the lead-plate type.

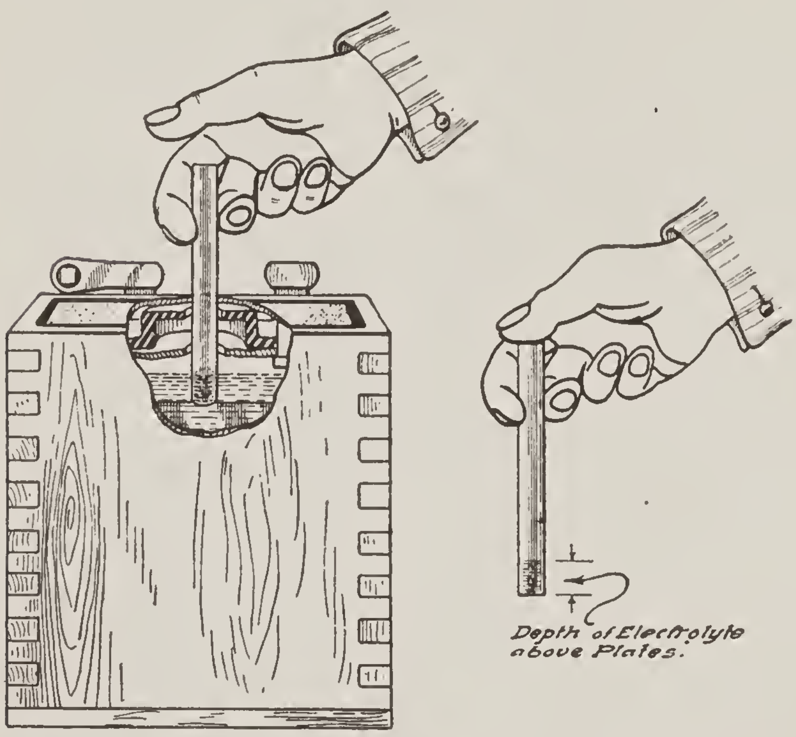


Fig. 456. Diagram Showing Method of Measuring Height of Electrolyte over Plates
Courtesy of U. S. Light and Heat Corporation, Niagara Falls, New York

CARE OF THE BATTERY

The following instructions are given about in the order in which it is necessary to apply them in the care of a storage battery.

Adding Distilled Water. In order to function properly, the plates in the cells must be covered by the electrolyte at all times to a depth of half an inch. Fig. 456 shows a handy method of determining this definitely. A small piece of glass tube, open at both ends, is inserted in the vent hole of the battery until it rests on the tops of the plates. A finger is then pressed tightly on top of the upper end of the tube, and the tube is withdrawn. It will bring with it at its lower end an amount of acid equivalent to the depth over the plates. This should always be returned to the same cell from which it was taken. The electrolyte consists of sulphuric acid and water. The acid does not evaporate, but the water does. The rapidity with which the water evaporates will depend upon the conditions of charging. For example, if a car is constantly driven on long day runs and gets very little night use, the storage battery is likely to be contin-

ually overcharged and may need the addition of water to the electrolyte as often as every three days, whereas, in ordinary service, once a week would be sufficient. Even with intermittent use, the battery should not be allowed to run more than two weeks without an inspection of the level of the electrolyte and the addition of distilled water, if necessary. Distilled water is always specified, since the presence of impurities in the water would be harmful to the battery, this being particularly the case where they take the form of iron salts. Where it is not convenient to procure distilled or rain water in sufficient quantities, samples of the local water supply may be submitted to any battery manufacturer for analysis.

While it is necessary to maintain the electrolyte one-half inch over the plates, care must be taken not to exceed this, for, if filled above this level, the battery will flood when charged, owing to the solution with the increasing temperature. The best time for adding water is just before the car is to be taken out for several hours of use. It may be done most conveniently with a glass and rubber syringe of the type used with the hydrometer. Care should be taken when washing the car to see that no water is allowed to enter the battery box, as it is likely to short-circuit the cells across their lead connectors and to carry impurities into the cells themselves.

Adding Acid. When the level of the electrolyte in the cell becomes low, it is, under normal conditions, caused by the evaporation of the water, and this loss should be replaced with water only. *There being no loss of acid, it should never be necessary to add acid to the electrolyte during the entire life of the battery.* When a jar leaks or is accidentally upset, and some of the solution lost, the loss should be replaced with electrolyte of the same specific gravity as that remaining in the cell, and not with full strength acid nor with water alone. The former would make the solution too heavy, while the latter would make it too weak. Consequently, unless acid is actually known to have escaped from the cell, none should ever be added to it. Under the sections on the Hydrometer and Specific Gravity, further reasons are given why no acid or electrolyte should be added to the cell under normal conditions, and the causes which would seem to make the addition of acid necessary are explained.

Hydrometer. Next to the regular addition of distilled water to the cells, the garage man will be called upon most frequently to

test the condition of the cells with the hydrometer. This is termed taking the specific gravity and is one of the most important tests in connection with the care of the battery. The specific gravity of a liquid is determined by means of an instrument consisting of a weighted glass tube having a scale marked on it. This instrument is the hydrometer, and in distilled water at 60 degrees it should sink until the scale comes to rest at the surface of the liquid at the division 1.000. The lighter the liquid, the further the instrument will sink in it; the heavier the liquid, the higher the instrument will float. For constant use in connection with the care of lighting and starting batteries, the hydrometer shown in Fig. 457 will be found the most convenient. Where the battery is located on the running board of the car, the test may be made without removing the syringe from the cell, but care must be taken to hold it vertical to prevent the hydrometer from sticking to the sides of the glass barrel. Wherever possible, the reading should be made without removing the syringe from the vent hole of the cell, so that the electrolyte thus withdrawn may always be *returned to the same cell.* Where the battery is located in a position difficult of access, as under the floor boards, the syringe may be drawn full of electrolyte and then lifted out; as the soft rubber plug in the bottom of the glass barrel is in the form of a trap, when the instrument is held vertical, the solution will not run out while the reading is being taken.

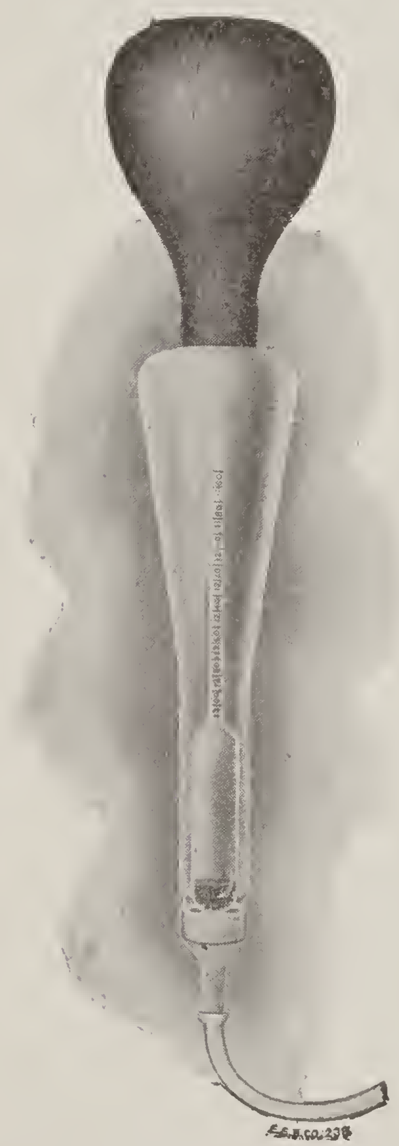


Fig. 457. Syringe Hydrometer Set

Failure to replace the electrolyte in the same cell from which it was taken will result in destroying the uniformity of the cells. For example, if electrolyte has been withdrawn from cell No. 1 of the battery and, after taking the reading, it is put into cell No. 2, the amount taken from No. 1 must later be made up by adding water, and the solution will be that much weaker, while the electrolyte of No. 2 will be correspondingly stronger.

Hydrometer Tests. In taking a hydrometer reading, first see that the instrument is not held by the sides of the glass syringe barrel; then note the level of the instrument in the liquid by looking at it from below, i.e., hold it up above the level of the eye. Reading the hydrometer in this way is found to give more accurate results than looking down upon it. While the hydrometer affords the best single indication of the condition of the battery—the cells should test 1.250 to 1.300 when fully charged and 1.150 when fully discharged, below which point they should never be allowed to go—there are conditions under which the instrument may be entirely misleading. For example, when fresh distilled water is added to a cell to bring the solution up to the proper level, the additional water does not actually combine with the electrolyte until the cell has been on charge for some time. Consequently, if a hydrometer reading were taken of that particular cell just after the water had been added, the test would be misleading, as it would apparently show the cell to be nearer the fully discharged state than it actually was, owing to the low specific gravity of the electrolyte. If, on the other hand, fresh electrolyte or pure acid has been added to a cell just prior to taking readings, and without the knowledge, of the tester the reading would apparently show the battery to be fully charged, whereas the reverse might be the case. In this instance, the specific gravity would be higher than it should be. To determine accurately the condition of the cells in such circumstances, the hydrometer readings would have to be checked by making tests with the voltmeter, as described later.

Under average conditions, however, the hydrometer alone will closely indicate the state of charge, and its use should always be resorted to whenever there is any question as to the condition of a battery. For instance, an irate owner will sometimes condemn the battery for failure of the starting motor to operate and will be absolutely positive that the battery has been fully charged, since he has been driving in daylight for hours. The hydrometer reading will show at once whether the battery is charged or not. If it is not, it will indicate either that the generator, its regulator, or the battery cut-out are not working properly, or that there is a short-circuit or a ground somewhere in the lighting or ignition circuits which permits the battery to discharge itself. Another more or less common complaint,

the cause of which may be definitely assigned one way or the other by the aid of the hydrometer is that "the battery is not holding its charge". Except where it is allowed to stand for long periods without use, as where a car is laid up for a month or more, there is no substantial decrease in the capacity simply through standing, unless the battery is allowed to stand in a discharged condition.

Consequently, the owner's impression that the charge of the battery is mysteriously leaking away overnight through some shortcoming of the cells themselves is not correct. If there is a fault, it is probably in the wiring; or a switch may have been left on inadvertently; or, as is very often the case, the car is not driven long enough in daylight to permit the generator to charge the battery sufficiently. When driving at night with all lights on, as is commonly the custom, the generator supplies very little current in excess of that required by the lamps. As a result, the battery receives but a fraction of its normal charge, so that one or two attempts to use the starting motor exhaust it. A hydrometer test made just before using the starting motor will show that there is only a small fraction of a charge in the cells, so that they are not capable of supplying sufficient current to turn the engine over longer than a few seconds. The hydrometer is equally valuable in indicating when a battery is being overcharged, though this is a condition which carries its own indication, known as gassing, which is described in detail under that head.

Variations in Readings. Specific-gravity readings between 1.275 and 1.300 indicate that the battery is fully charged; between 1.200 and 1.225, that the battery is more than half discharged; between 1.150 and 1.200, that the battery is quickly nearing a fully discharged condition and must be recharged very shortly, otherwise injury will result. Below 1.150 the battery is entirely exhausted and must be recharged immediately to prevent the plates from becoming sulphated, as explained in the section covering that condition.

Where the specific gravity in any cell tests more than 25 points lower than the average of the other cells in the battery, it is an indication that this cell is out of order. Dependence should not be placed, however, on a single reading where there is any question as to the specific gravity. Take several readings and average them. Variations in cell readings may be caused by internal short-circuits in the cell; by putting too much water in the cell and causing a loss

of electrolyte through flooding or overflowing; or by loss of electrolyte from a cracked or leaky jar. Internal short-circuits may result from a broken separator or from an accumulation of sediment in the mud space of the jars reaching the bottom of the plates.

Quite a substantial percentage of all the troubles experienced with starting batteries, which are only too often neglected until they give out, is caused by letting the electrolyte get too low in the jars. The effect of this is to weaken the battery, causing it to discharge more readily, and frequently resulting in harmful sulphating of the plates and injury to the separators. When such sulphating occurs, it permits the plates to come into contact with each other, and an internal short-circuit results. The importance of always maintaining the electrolyte one-half inch above the tops of the plates will be apparent from this.

One of the most frequent causes of low electrolyte in a single cell is the presence of a cracked or leaky jar. If one of the cells requires more frequent addition of water than the others to maintain the level of its electrolyte, it is an indication that it is leaking. Where all the cells of a battery require the addition of water at unusually short intervals, it is an indication that the battery is being constantly overcharged. (See Gassing.) Unless a leaky jar is replaced immediately, the cell itself will be ruined, and it may cause serious damage to the remainder of the battery. Jars are often broken owing to the hold-down bolts or straps becoming loose, thus allowing the battery to jolt around on the running board, or they may be broken by freezing. The presence of a frozen cell in a battery shows that it has been allowed to stand in an undercharged condition in cold weather, as a fully charged cell will not freeze except at unusually low temperatures.

Frozen Cells. In some cases, the cells may freeze without cracking the jars. This will be indicated by a great falling off in the efficiency of the cells that have suffered this injury, or in a totally discharged condition which cannot be remedied by continuous charging. In other words, the battery is dead and the plates are worthless except as scrap lead. In all cases where cells have been frozen, whether the jar has cracked or not, the plates must be replaced at once. It must always be borne in mind that low temperatures seriously affect the efficiency of the storage battery and that

care should be taken to keep it constantly in a charged condition. A variation in the temperature also affects the hydrometer readings themselves. The effect of the temperature on the hydrometer tests is explained under Adjusting the Specific Gravity.

Low Cells. When one cell of the battery tests more than 25 points below the specific gravity of the others, as shown by the average of several readings taken of each, it should be placed on charge separately from an outside source of current. This may be done without removing it from the car or disconnecting it from the other cells, since the charging leads may be clipped to its terminal posts. If no other facilities are available and direct-current service is at hand, use carbon lamps as a resistance in the manner illustrated on another page. As the normal charging rate of the average starting battery is 10 to 15 amperes or more, that many 32-c.p. carbon filament lamps may be used in the circuit. Where only alternating current is available, a small rectifier, as described under Charging from Outside Sources, will be found most convenient in garages not having enough of this work to warrant the installation of a motor-generator. After the low cell has been on charge for an hour or two, note whether or not its specific gravity is rising, by taking a hydrometer reading. If, after several hours of charging, its specific gravity has not risen to that of the other cells, it is an indication that there is something wrong with the cell, and it should be cut out. (See Replacing a Jar and Overhauling the Battery.)

Adjusting the Specific Gravity. Except in such cases as those mentioned under Hydrometer, where water has been added to the electrolyte just before testing, or electrolyte has been added without the knowledge of the tester, specific gravity of the electrolyte is the best indication of the condition of the cell, and the treatment to be given should always be governed by it. As explained in the section on Action on Charge and Discharge, the acid of the electrolyte combines with the active material of the plates to produce the current on discharge. The further the cell is discharged the more acid there will be in the plates, and the less in the solution. Consequently, low-gravity readings practically always mean lack of acid in the solution, and that implies lack of charge. Unless there is something wrong with the cell, charging will restore the acid to the electrolyte and bring the specific-gravity readings up to normal. In case a jar

is leaking or has been overturned and lost some of its electrolyte, no amount of charging will bring its specific gravity up to the proper point.

The gravity readings of the cells vary somewhat in summer and winter, and they also decrease with the age of the plates, but the battery will continue to give good service as long as its specific gravity rises to between 1.250 and 1.300 when fully charged. In case it rises above 1.300, there is an indication that excess acid has been added to the electrolyte, and this must be corrected by drawing off some of the electrolyte with the syringe and replacing it with distilled water. A gradually decreasing specific gravity in all the cells of a battery is an indication that sediment is accumulating in the bottom of the jars and that the battery, if of the old type with low mud space, requires washing; if of the later type with high mud space, that its elements require renewal. Before accepting this conclusion, however, make certain that the low reading is not due to insufficient charging. In actual practice, starter batteries seldom remain long enough in service without overhauling even to need washing.

Many starter batteries are kept in an undercharged condition so constantly, owing to frequent use of the starting motor with but short periods of driving in between, that they should be put on charge from an outside source at regular intervals. In fact, this is the only method of determining definitely whether the battery itself is really at fault or whether it is the unfavorable conditions under which it is operating. Where the cells give a low reading, no attempt should ever be made to raise the specific gravity of the electrolyte by adding acid, until the battery has been subjected to a long slow charge. The maximum specific gravity of the electrolyte is reached when all the acid combined in the active material of the plates has been driven out by the charging current. Adding acid will increase the specific gravity, but it will not increase the condition of charge; it will simply give a false indication of a charged condition. For example, if the electrolyte of a cell tested 1.225, and, without giving it a long charge, acid were added to bring the specific gravity up to 1.275, it would then rise to 1.325 if put on charge, showing that 50 points of acid had remained combined in the plates when the low readings were taken.

The necessity for adjusting the specific gravity of the electrolyte in a cell can only be determined by first bringing it to its true maximum. To do this with a starter battery, it must be put on charge from an outside source at a low rate, say 5 amperes, and kept on charge continuously until tests show that the specific gravity of the electrolyte has ceased to rise. This may take more than twenty-four hours, and readings should be taken every hour or so, toward the end of the charge. Should the battery begin to gas violently while tests show that the specific gravity is still rising, the charging current should be reduced to stop the gassing, or, if necessary, stopped altogether for a short time and then renewed.

If after this prolonged charge, the specific gravity is not more than 25 points below normal, some of the solution may be drawn off with the syringe and replaced with small quantities of 1.300 electrolyte, which should be added very gradually to prevent bringing about an excess. Should the specific gravity be too high at the end of the charge, draw off some of the electrolyte and replace it with distilled water to the usual level of one-half inch over the plates. A charge of this kind is usually referred to as a conditioning charge and, given once a month, will be found very greatly to improve starter batteries that are constantly undercharged in service.

Temperature Corrections. All specific-gravity readings mentioned are based upon a temperature of 70° F. of the electrolyte, and as the electrolyte, like most other substances, expands with the heat and contracts with the cold, its specific gravity is affected by variations of temperature. This, of course, does not affect its strength, but as its strength is judged by its specific gravity, the effect of the temperature must be taken into consideration when making the tests. The temperature in this connection is not that of the surrounding air but that of the electrolyte itself, and as the plates and solution of a battery increase in temperature under charge, the electrolyte may be 70° F. or higher, even though the outside air is close to zero. Consequently, the only method of checking this factor accurately is to insert a battery thermometer in the vent hole of the cell. If, on the other hand, the battery has been standing idle for some time in a cold place, the electrolyte has the same temperature as the surrounding air, and a hydrometer reading taken without a temperature correction would be very misleading.

For example, assume that the car is standing in a barn in which the temperature is 20° F. and that it has not been running for some time so that the electrolyte is as cold as the surrounding air. A hydrometer reading shows the specific gravity of the electrolyte to be 1.265, which would indicate that the battery was approximately fully charged. But the correction for temperature amounts to one point (.001) for each three degrees above or below 70° F., and in this case a difference of 50 degrees would have to be allowed for. This amounts to practically 18 points, and the specific gravity of the cells is 1.265 minus 18, or 1.247. The battery is accordingly three-quarters charged, instead of fully charged as the uncorrected reading would appear to indicate. The electrolyte contracts with the drop in temperature, and its specific gravity becomes correspondingly higher without any actual increase in its strength. The opposite condition will be found when the battery has commenced to gas so violently that the temperature of the electrolyte is raised to 100° to 105° F. At the former figure there would be a difference of 30 degrees, or 10 points, to allow for, in which case a specific gravity reading of 1.265 would actually be 1.275. Hydrometer scales, with a a temperature scale showing at a glance the corresponding correction necessary, simplify the task of correcting the readings; but to do this properly a battery thermometer must be employed, as the temperature of the electrolyte itself is the only factor to be considered.

Gassing. When an electric current is sent through a storage-battery cell, it immediately attacks the lead sulphate into which the active material of both the positive and the negative plates has been converted during the discharge and begins to reconvert it into peroxide of lead at the positive plate and into spongy metallic lead at the negative. As long as there is an ample supply of this lead sulphate on which the current may work, as in a fully discharged battery, the entire amperage being sent through the battery is restricted to carrying on this process. In other words, the current will always do the easiest thing first by following the path of least resistance. When the cell is in a discharged state, the easiest thing to do is to decompose the lead sulphate. As there is a comparatively large amount of this lead sulphate in a fully discharged battery, a correspondingly large amount of current can be used in charging at the start. But as the amount of sulphate progressively decreases with the charge,

a point is reached at which there is no longer sufficient sulphate remaining to utilize all the current that is passing through the cell.

The excess current will then begin to do the next easiest thing, which is to decompose the water of the electrolyte and liberate hydrogen gas. This gassing is not owing to any defect in the battery, as some owners seem to think, but is simply the result of overcharging it. In one instance, a car owner condemned the starting battery with which his machine was equipped, for the reason that it was "always boiling". In fact, it "boiled" itself to pieces and had to be replaced by the manufacturer of the car after only a few months of service; while, as a matter of fact, the conditions under which the car was driven were wholly responsible. It was used for long runs in the day time with infrequent stops, and was rarely run at night; therefore, the battery was continually charging but seldom had an opportunity to discharge.

This erroneous impression is also closely interlinked with another that is equally common and equally harmful. This is that one of the functions of the battery cut-out is to break the circuit and prevent the battery from becoming overcharged. It is hardly necessary to add that this is not one of its functions, but that as long as the generator is being driven above a certain speed, the cut-out will keep the battery in circuit, and the generator will continue to charge it. Its only purpose is to prevent the battery from discharging itself through the generator when the speed of the generator falls to a point where its voltage would be overcome by that of the battery unless the battery were automatically disconnected. The cut-out does not protect the battery from being overcharged; only the driver or the garage man can do that by noting the conditions under which the car is operated and taking precautions to prevent the battery from overcharging.

Gassing is simply an indication that too much current is being sent into the battery. Another indication of the same condition is the necessity for refilling the cells with distilled water at very short intervals, as an excess charge raises the temperature of the electrolyte and causes rapid losses by evaporation. That is the reason why it is likely to be so harmful to the battery unless remedied, as if allowed to exceed 110° F., the active material is likely to be forced out of the grids, and the cells to be ruined. While it is essential

that the battery be fully charged at intervals and that it be always kept well charged, continuously overcharging it is likely to be as harmful as allowing it to stand undercharged. Where the conditions of service cannot be altered to remedy the trouble, the regulator of the generator should be adjusted to lower the charging rate, or, if nothing else will suffice, additional resistance, controlled by an independent switch, may be inserted in the charging circuit. (The U.S.L. system has a provision to safeguard the battery against overcharge, termed the touring switch.)

Higher Charge Needed in Cold Weather. While the regulator of the generator is set by the manufacturer to give the best average results, and some makers warn the user against altering its adjustment, experience has demonstrated that a fixed adjustment of the regulation will not suffice for cars driven under all sorts of service conditions, nor for the same car as used at different seasons of the year. The efficiency of the storage battery is at its lowest in cold weather, which is the time when the demand upon it is greatest. A battery that would be constantly overcharged during the summer may not get more than sufficient current to keep it properly charged in winter, though driven under similar conditions in both seasons. On the other hand, a battery that is generally undercharged under summer conditions of driving will be practically useless in winter, as it will not have sufficient current to meet the demands upon it.

It may be put down as a simple and definite rule that if the battery of a starting system never reaches the gassing stage, it is constantly undercharged and is rapidly losing its efficiency, as the sulphate remaining on the plates becomes harder with age and prevents the circulation of the electrolyte. Even when in the best condition, the electrolyte cannot reach all of the active material in the plates, so that any reduction means a serious falling off. Likewise, when a battery is constantly gassing, it is in a continuous state of overcharge and is apt to be entirely ruined in a comparatively short time. The danger from undercharging is known as sulphating—the plates become covered with a hard coating of lead sulphate that the electrolyte cannot penetrate—while that from overcharging is due to the electrolyte and the plates reaching a dangerous temperature (105° F. or over) at which the active material is apt to be stripped from the grids. The conditions of service, on the average, are such

that a battery can seldom be kept in good condition for any length of time on the charging current from the generator alone.

The hydrometer should be used frequently to keep track of its condition and, at least once a month, it should be given a long conditioning, or equalizing, charge, as it is variously termed. This charge is required because of the fact that, under ordinary conditions, a battery seldom receives a complete charge and that every time it is discharged without this being followed by a charge which is prolonged until the electrolyte has reached its maximum specific gravity, more lead sulphate accumulates in the plates. The object of the long charge is to convert this lead sulphate into peroxide of lead at the positive plate and into spongy metallic lead at the negative plate, as explained further under the head of Sulphating.

Sulphating. At the end of a discharge, both sets of plates are covered with lead sulphate. This conversion of the active material of the plates into lead sulphate, which takes place during the discharge, is a normal reaction and, as such, occasions no damage. But if the cells are allowed to stand for any length of time in a discharged condition, the sulphate not only continues to increase in bulk, but becomes hard. It is also likely to turn white, so that white spots on the plates of a battery when it is dismantled are an indication that the cells have been neglected. In this condition, the plates have lost their porosity to a certain extent and it is correspondingly more difficult for the charging current to penetrate the active material. When a battery has stood in a discharged condition for any length of time, it becomes sulphated. The less current it has in it at the time and the longer it stands, the more likely it is to be seriously damaged.

Where a car is used but little in the daytime, and then only for short runs with more or less frequent stops, the battery never has an opportunity to become fully charged. The demands of the starting motor and the lights are such that the battery is never more than half charged at any time. Consequently, there is always a certain proportion of the lead sulphate that is not reconverted, but which remains constantly in the plates. As already mentioned, this condition does not remain stationary; the sulphate increases in amount and the older portions of it harden. This represents a loss of capacity which finally reaches a point where the cells are

no longer capable of supplying sufficient current (holding enough of the charge, as the owner usually puts it) to operate the starting motor. A battery that has been operating under conditions of this kind is not prepared for the winter's service, which accounts for the great number of complaints about the poor service rendered by starting systems in the early part of every winter. As long as the weather is warm, the battery continues to supply sufficient current in spite of the abuse to which it is subjected, but when cold weather further reduces its efficiency, it is no longer able to meet the demand.

The only method of preventing this and of remedying it after it has occurred is the equalizing charge metioned in the preceding section. Long continued and persistent charging at a low rate will cure practically any condition of sulphate, the time necessary being proportionate to the degree to which it has been allowed to extend. It is entirely a question of time, and, as a high rate would only produce gassing, which would be a disadvantage, the rate of charge must be low. In case the cells show any signs of gassing, the charge must be further reduced.

Extra Time Necessary for Charging. The additional length of time necessary for charging a battery that has been constantly kept in an undercharged condition is strikingly illustrated by the following test made with an electric vehicle battery: The cells were charged to the maximum, and the specific gravity regulated to exactly 1.275 with the electrolyte just ½ inch above the tops of the plates, this height being carefully marked. The battery was then discharged and recharged to 1.265 at the normal rate in each case. The specific gravity rose from 1.265 to 1.275 during the last hour and a half of the charge. During the following twelve weeks, the battery was charged and discharged daily, each charge being only to 1.265, thus leaving 10 points of acid still in the plates. At the end of the twelve weeks, the charge was continued to determine the time required to regain the 10 points and thus restore the specific gravity to the original 1.275. Eleven hours were needed, as compared with the hour and half needed at first. This test further illustrates why it is necessary to give a battery an occasional overcharge or equalizing charge to prevent it becoming sulphated. Had the battery in question been charged daily to its maximum of 1.275 and discharged

to the same extent during the twelve weeks, $9\frac{1}{2}$ hours of the last charge would have been saved. These periods of time, of course, refer to the charging of the electric-vehicle battery, but they indicate in a corresponding manner the loss of efficiency suffered by the starting battery owing to its being continually kept in an undercharged condition.

Restoring Sulphated Battery. There are only three ways in which a battery may become sulphated: The first and most common of these is that it has not been properly charged; second, excess acid has been added to the electrolyte; third, an individual cell may become sulphated through an internal short-circuit or by drying out, as might be caused by failure to replace evaporation with water, or failure to replace promptly a cracked jar. The foregoing only holds good, however, where the sediment has not been allowed to reach the bottom of the plates, and where the level of the electrolyte has been properly maintained by replacing evaporation with distilled water.

To determine whether a battery is sulphated or not—it having been previously ascertained that it does not need cleaning (washing)—it should be removed from the car (the generator should not be run with the battery off the car without complying with the manufacturer's instructions in each case, usually to short-circuit or bridge certain terminals on the generator itself) and given an equalizing charge at its normal rate. The normal rate will usualy be found on the name plate of the battery. If the battery begins to gas at this rate, the rate must be reduced to prevent gassing, and lowered further each time the cells gas. Frequent hydrometer readings should be taken, and the charge should be continued as long as the specific gravity continues to increase. A battery is sulphated only when there is acid retained in the plates. When the specific gravity reaches its maximum, it indicates that there is no more sulphate to be acted upon, since, during the charge, the electrolyte receives acid from no other source. With a badly sulphated battery, the charge should be continued until there has been no further rise in the specific gravity of any of the cells for a period of at least twelve hours. Maintain the level of the electrolyte at a constant height by adding pure water after each test with the hydrometer (if water were added just before taking readings, the water would rise to the top of the solution

and the reading would be valueless). With a battery on a long charge, the battery thermometer should be used at intervals to check the temperature of the electrolyte, and the hydrometer readings should be corrected in accordance with the temperature.

Specific Gravity too High. Should the specific gravity of any of the cells rise above 1.300, draw off the electrolyte down to the top of the plates and put in as much distilled water as possible without flooding the cell. Continue the charge and, if the specific gravity again exceeds 1.300, this indicates that acid has been added during the previous operation of the battery. The electrolyte should then be emptied out and replaced with distilled water and the charge continued. The battery can only be considered as restored to efficient working condition when there has been no rise in the specific gravity of any of the cells during a period of at least twelve hours of continuous charging.

Upon completion of the treatment, the specific gravity of the electrolyte should be adjusted to its proper value of 1.280, using distilled water or 1.300 acid, as necessary. In cases where one cell has become sulphated while the balance of the battery is in good condition, it is usually an indication that there is a short-circuit or other internal trouble in the cell, though this does not necessarily follow. To determine whether or not it is necessary to dismantle the cell, it may first be subjected to a prolonged charge, as above described. If its specific gravity rises to the usual maximum, the condition may be considered as remedied without taking the cell apart. It is the negative plate which requires the prolonged charge necessary to restore a sulphated battery. When sulphated, the active material is generally of light color and either hard and dense or granular and gritty, being easily disintegrated. Unless actually buckled or stripped of considerable of their active material, the positive plates are unchanged in appearance and can be restored to operative condition, though their life will be shortened by this abuse. Sulphated plates of either type should be handled as little as possible. By keeping close check with the hydrometer on the condition of the starting battery and, where it is not being kept in an overcharged condition constantly, giving it an equalizing charge once a month, the charge being continued until the cells no longer increase in specific gravity after a period of several hours, and the

reading of all the cells being within at least 25 points of each other, sulphating may be avoided entirely.

Internal Damage. This trouble is usually caused by a short-circuit, owing either to an accumulation of sediment reaching the plates or to the breaking of a separator, which may be caused by the active material being forced out of the grid, usually termed buckling, which is caused by overheating. It is important to be able to determine whether or not the low efficiency of a certain cell is caused by internal trouble without having to dismantle the cell. The repair man's most important aid for this class of work is the high-grade portable voltmeter mentioned in connection with other tests of the starting and lighting system.

Voltage Tests. Under some conditions, the voltmeter will also indicate whether the battery is practically discharged or not, but, like the hydrometer, it should not be relied upon alone. To insure accuracy, it must be used in conjunction with the hydrometer. Since a variation as low as .1 (one-tenth) volt makes considerable difference in what the reading indicates regarding the condition of the battery, it will be apparent that a cheap and inaccurate voltmeter would be a detriment rather than an aid. The instrument illustrated in connection with tests of other parts of starting and lighting systems (see Delco) is of the type required for this service. Complete instructions for its use will be received with the instrument, and these must be followed very carefully to avoid injuring it. For example, on the three-volt scale, but one cell should be tested; attempting to test the voltage of more than one cell on this scale is apt to burn out the three-volt coil in the meter. The total voltage of the number of cells to be tested must never exceed the reading of the particular scale being used at the time; otherwise, the coil of the scale in question will suffer, and the burning out of one coil will make it necessary to rebuild the entire instrument.

Clean Contacts Necessary. Where the voltage to be tested is so low, a very slight increase in the resistance will affect it considerably and thus destroy the accuracy of the reading. Make certain that the place on the connector selected for the contact point is clean and bright, and press the contact down on it firmly. To insure a clean bright contact point, use a fine file on the lead connector. The contact will be improved by filing the test points fairly sharp.

Even a thin film of dirt or a weak contact will increase the resistance to a point where the test is bound to be misleading. The positive terminal of the voltmeter must be brought into contact with the positive terminal of the battery, and the negative terminal of the voltmeter with the negative of the battery. If the markings of the cell terminals are indistinct, connect the voltmeter across any one cell. In case the pointer butts up against the stop at the left instead of giving a reading, the connections are wrong and should be reversed; if the instrument shows a reading for one cell, the positive terminal of the voltmeter is in contact with the positive of the battery. This test can be made with a voltmeter without any risk of short-circuiting the cell, as the voltmeter is wound to a high resistance and will pass very little current. Connecting an ammeter directly across a cell, however, would short-circuit it and instantly burn out the instrument.

How to Take Readings. It is one of the peculiarities of the storage cell that when on "open circuit", i.e., not connected in circuit with a load of any kind, it will always show approximately two volts, regardless of whether it is almost fully charged or almost the reverse. Consequently, voltage readings taken when the battery is on open circuit, i.e., neither charging nor discharging, are valueless, *except when a cell is out of order*. Therefore, a load should be put on the battery before making these tests. This can be done by switching on all the lamps. With the lights on, connect the voltmeter, as already directed, and test the individual cells. If the battery is in good condition, the voltage readings, after the load has been on for about ten minutes, will be but slightly lower than if the battery were on open circuit. This should amount to about .1 (one-tenth) volt. Should one or more of the cells be completely discharged, the voltage of these cells will drop rapidly when the lamps are first switched on and, when a cell is out of order, will sometimes show a reverse reading. Where the battery is nearly discharged, the voltage of each cell will be considerably lower than if the battery were on open circuit, after the load has been on for five minutes.

Detecting Deranged Cells. To distinguish the difference between cells that are merely discharged and those that are out of order, put the battery on charge, either from an outside source or by starting the engine, which should always be cranked by hand

when any battery trouble is suspected. Then test again with the voltmeter. If the voltage of each cell does not rise to approximately two volts after the battery has been on charge for ten minutes or more, it is an indication of internal trouble which can be remedied only by dismantling the cell. (See instructions under that heading.)

Temperature Variations in Voltage Test. When making voltage tests, it must be borne in mind that the voltage of a cold battery rises slightly above normal on charge and falls below normal on discharge. The reverse is true of a warm battery in hot weather, i.e., the voltage will be slightly less than normal on charge and higher than normal on discharge. As explained in connection with hydrometer tests of the electrolyte, the normal temperature of the electrolyte may be regarded as 70° F., but this refers only to the temperature of the liquid itself as shown by the battery thermometer, and not to the temperature of the surrounding air. For the purpose of simple tests for condition, voltage readings on discharge are preferable, as variations in readings on charge mean little except to one experienced in the handling of storage batteries.

Joint Hydrometer and Voltmeter Tests. As already explained above, neither the hydrometer nor the voltmeter reading alone can always be taken as conclusive evidence of the condition of the battery. There are conditions under which one must be supplemented by the other to obtain an accurate indication of the state of the battery. In making any of the joint tests described below, it is important to take into consideration the four points following:

(1) The effect of temperature on both voltage and hydrometer readings.

(2) Voltage readings should be taken only with the battery discharging, as voltage readings on an idle battery in good condition indicate little or nothing.

(3) Never attempt to use the starting motor to supply a discharge load for the battery, because the discharge rate of the battery is so high while the starting motor is being used that even in a fully charged battery it will cause the voltage to drop rapidly.

(4) The voltage of the charging current will cause the voltage of a battery in good condition to rise to normal or above the moment it is placed on charge, so that readings taken under such circumstances are not a good indication of the condition of the battery.

In any battery which is in good condition, the voltage of each cell at a normally low discharge rate, i.e., 5 to 10 amperes for a starter battery of the 6-volt type or slightly less for a higher voltage battery, will remain between 2.1 and 1.9 volts per cell until it begins to approach the discharged condition. A voltage of less than 1.9 volts per cell indicates either that the battery is nearly discharged or is in a bad condition. The same state is also indicated when the voltage drops rapidly after the load has been on for a few minutes. The following joint hydrometer and voltmeter tests issued by the Prest-O-Lite Company of Indianapolis will be found to cover the majority of cases met with in actual practice.

(1) A voltage of 2 to 2.2 volts per cell with a hydrometer reading of 1.275 to 1.300 indicates that the battery is fully charged and in good condition.

(2) A voltage reading of less than 1.9 volts per cell, with a hydrometer reading of 1.200 or less indicates that the battery is almost completely discharged.

(3) A voltage reading of 1.9 volts or less per cell, with a hydrometer reading of 1.220 or more, indicates that excess acid has been added to the cell. Under these conditions, lights will burn dimly, although the hydrometer reading alone would appear to indicate that the battery was more than half charged.

(4) Regardless of voltage—high, low, or normal—any hydrometer reading of over 1.300 indicates that an excessive amount of acid has been added.

(5) Where a low voltage reading is found, as mentioned in cases 2 and 3, to determine whether the battery is in bad order or merely discharged, stop the discharge by switching off the load, and put the battery on charge, cranking the engine by hand, and note whether the voltage of each cell rises promptly to 2 volts or more. If not, the cell is probably short-circuited or otherwise in bad condition.

Cleaning a Battery. Electric vehicle batteries usually receive such careful and intelligent attention that the life of the battery is measured by the maximum number of charges and discharges of which the plates are capable under favorable conditions. To prevent any possibility of short-circuiting, a cell is cut out and opened after a certain number of discharges, and if the amount of sediment in the jar is approaching the danger point, the entire battery is opened and cleaned. With the old type starter cell, this would be necessary if the battery received the proper attention; with the modern or high mud-space type, cleaning is never necessary as the space is designed to accommodate all the active material that can fall from the plates without touching their under sides. As a matter of fact, the batteries of starting and lighting systems never last long enough to require cleaning out. They are either kept undercharged and

thus become badly sulphated, or they are overcharged to a point where the temperature passes the danger mark frequently. When hot, the acid attacks and injures the wood separators so that the average life is about one year. Exceptions to this are found in those cases where the battery has been given proper attention, which results in unusually long life without the necessity of opening the cells for either cleaning or the insertion of new separators. These cases are so in the minority, however, that the battery manufacturers usually recommend that the car owner have his starting battery overhauled in the fall to put it in the best of condition for the winter as well as for the following year. Even where a battery has been

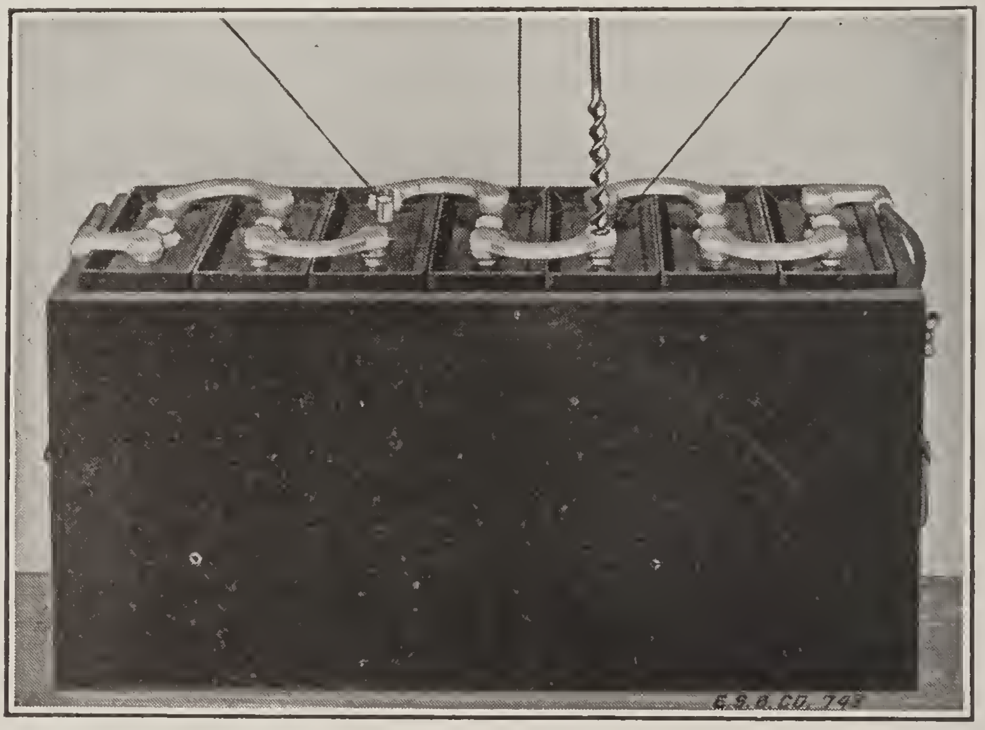


Fig. 458. Drilling Off Connectors
Courtesy of Electric Storage Battery Company, Philadelphia, Pennsylvania

given conscientious attention, the conditions of charging on the automobile are likely to vary so radically that it will be found almost impossible to keep the cells in a good state. Consequently, it is considered the best practice to give all starter batteries an overhauling once a year. The method of doing this is described in succeeding sections.

Replacing a Jar. When a cell requires the addition of distilled water more often than the other cells of the battery, or does not test to the same specific gravity as the others, it is usually an indication that there is a leak in the jar. Failure to give the same specific-gravity reading is not proof of this condition, as the cell may be

low from other causes, but the loss of electrolyte is certain evidence of it. The only remedy is to replace the jar at fault.

After locating the cell in question, carefully mark the connectors so as to be sure to replace them the same way. Disconnect the cell from the others in the battery. This may be done either with the aid of brace and bit, which is used to drill down through the post of the connector, Fig. 458, or with a gasoline torch which should be applied carefully to the strap at the post. When the metal has become molten, pry the strap up on the post with a piece of wood. Do not use a screwdriver or other metal for this purpose as it is apt to short-circuit one or more of the cells. Care must also be taken not to apply so much heat that the post itself will be melted as this would make it difficult to reconnect the cell. For one not accustomed to handling the torch, it will be safer to drill out the post, as illustrated. Lift the complete cell out of the battery box and then use the torch to warm the jar around the top to soften the sealing compound that holds the cover, Fig. 459. Grip the jar between the feet, take hold of the two connectors and pull the element almost out of the jar, Fig. 460. Then grip the elements near the bottom to prevent the plates flaring out while transferring them to the new jar, taking care not to let the outside plates start down the outside of the jar, Fig. 461. After the element is in the new jar, reseal the cell by pressing the sealing compound into place with a hot putty knife. Fill the cell with 1.250 electrolyte to the proper point, the old electrolyte being discarded.

Fig. 459. Softening Sealing Compound on Cell

Before replacing the connectors, clean both the post and the inside of the eye of the connector by scraping them smooth with a knife. When the connector has been placed in position, tap it down firmly over the post to insure good contact. To complete the connection, melt the lead of the connector and the post at the top so that they will run together, and while the lead is still molten,

melt in some more lead until the eye of the connector is filled level. This is termed lead burning and is described at greater length in a succeeding section. Where no facilities are at hand for carrying it out, it may be done with an ordinary soldering copper. The copper is brought to a red heat so that all the tinning is burned off, and no flux of any kind is used. The method of handling the soldering copper and the lead-burning strip to supply the extra metal required to fill the eye is shown in Fig. 462.

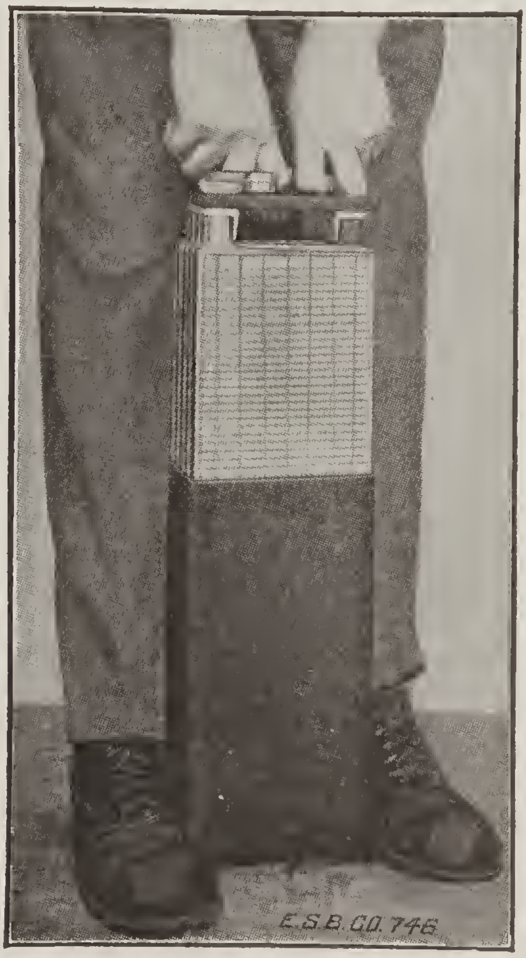


Fig. 460. Lifting Elements out of Jar by Hand

Fig. 461. Installing Elements in Jar

Courtesy of Electric Storage Battery Company, Philadelphia, Pennsylvania

Put the battery on charge from an outside source, and when the cells begin to gas freely, reduce the current to half the finishing rate given on the battery name plate and charge at this rate as long as there is any rise in the specific gravity of the electrolyte in this or any of the other cells. The maximum gravity has been reached when there has been no rise in the specific gravity for a period of three hours. If the gravity of the cell having the new jar is then over 1.280, draw off some of the electrolyte and replace it with distilled water. If the gravity is below 1.270, draw off some of the electrolyte and replace it with 1.300 electrolyte. If necessary

to put in 1.300 electrolyte, allow the battery to continue charging for about one-half hour longer at a rate sufficient to cause gassing, which will cause the stronger acid to become thoroughly mixed with the rest of the electrolyte in the cell.

Overhauling the Battery. As already mentioned, it will be found desirable to overhaul the majority of starter batteries at least once a year. The expense to the car owner will be less than

Fig. 462. Reburning Battery Connectors with Soldering Iron
Courtesy of Electric Storage Battery Company, Philadelphia, Pennsylvania

the cost of the frequent attention required by a run-down battery with complete renewal at no distant date, and the service rendered by the battery will be much improved. The best time of year to do this is in the late fall, so that the battery may be at its best during the cold weather. Before undertaking the work, have on hand a complete renewal set of rubber and wood separators as well as sufficient fresh acid of 1.300 specific gravity with which to mix fresh electrolyte. Use the good separators, particularly the rubber ones.

Dismounting Cells. Remove the connectors by drilling, heating, or pulling (in the same manner as a wheel is pulled), and loosen the jar covers by heating or running a hot putty knife around their edges so that they may be lifted off. The covers should be washed in hot water and then stacked one on top of the other with heavy weight on them to press them flat. Lift the jars out of the battery box and note whether any of them have been leaking. A cracked jar should of course be replaced. Treat one cell at a time, by pulling the element out of the jar with the aid of the pliers, meanwhile holding the jar with the feet. Lay the element on the bench and

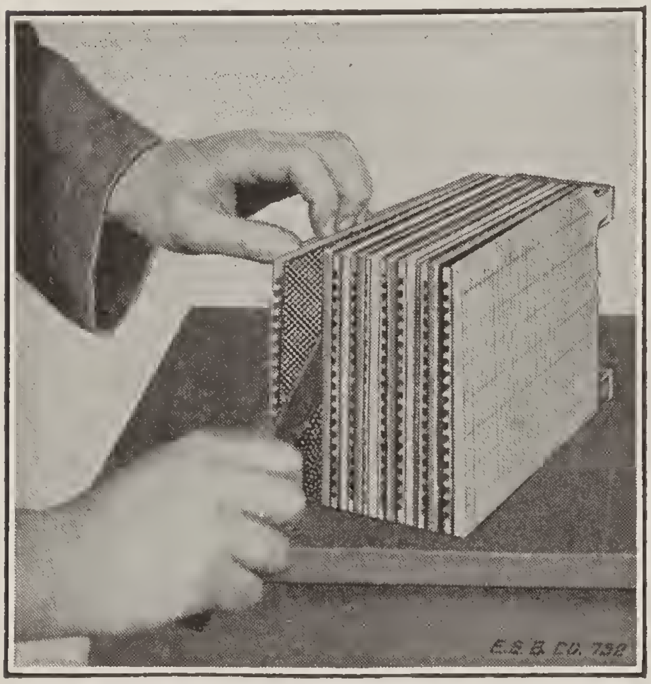


Fig. 463. Removing Old Separators from Elements

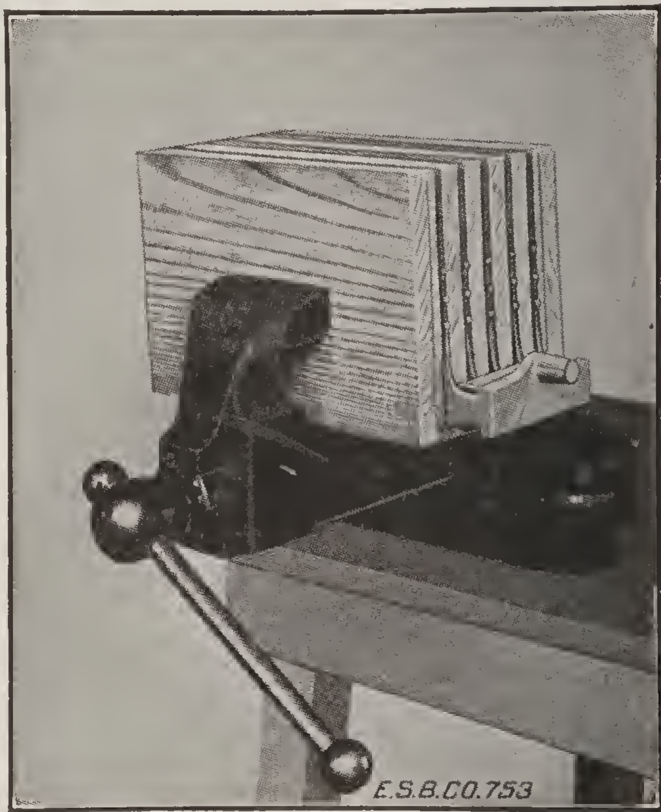


Fig. 464. Pressing Negative Group

Courtesy of Electric Storage Battery Company, Philadelphia, Pennsylvania

spread the plates slightly to permit removing the separators, taking care not to injure the rubber sheets, Fig. 463. Separate the positive group from the negative. If the active material of the negative be swollen beyond the surface of the grid, press it back into position before it has a chance to dry, placing boards of suitable thickness between the plates and carefully squeezing the group between heavy boards in a vise or press, as shown in Fig. 464. Boards of sufficient size and thickness must be used between the plates or breakage will result. Charged negative plates will become hot in a short time when exposed to the air and, in this event, should be allowed to cool before reassembling. Remove any loose particles adhering

to the positive plates by passing a smooth wood paddle over the surface but *do not wash the positive plates.*

Treating the Plates. If the positive plates show signs of buckling or stripping of the active matter, or if the negative plates have the light spotted appearance indicative of sulphating, it may be necessary to replace them altogether. In case sulphating appears to be the only trouble, the groups should be reassembled in an open jar with distilled water and given a long, slow charge, testing with the hydrometer at frequent intervals to note whether the specific gravity is rising or not. Twenty-four hours or more may be necessary for this charge, and two or three days will be nothing unusual. This charging, of course, is carried on from the lighting mains through a rectifier or a motor-generator, unless direct-current service is available. If it is necessary to prolong the charge over two or three days, and the specific gravity still continues to rise slowly, it may be preferable to replace the plates.

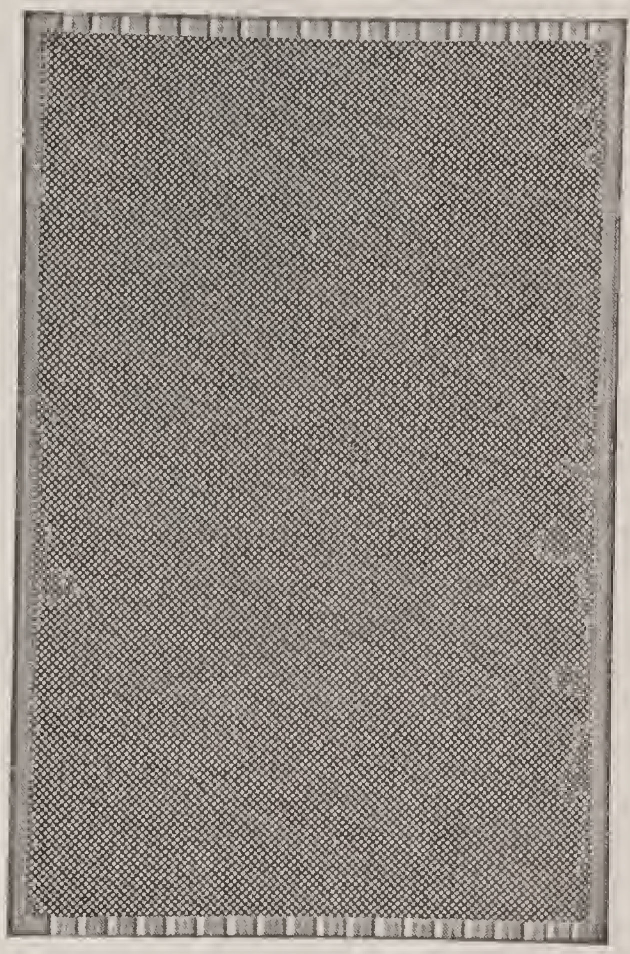


Fig. 465. Wood and Rubber Separator

Reassembling Battery. Wash all the sediment out of the jars, also wash and save the rubber sheets, unless they happen to be broken, but throw away the old wood separators. The rubber sheets should be placed in clean running water for about a quarter of an hour. Reassemble the positive and negative groups with the plates on edge in order to insert the separators. Place a rubber separator against the grooved side of a wood separator, Fig. 465, and insert a positive plate near the center of the element. The rubber sheet must be against the positive plate, and the wood separator against the negative plate. In this manner insert separators in all the spaces, working in both directions from the center. Care must be taken *not to omit a separator as that would short-circuit the cell.*

The separators should be practically flush with the bottoms of the plates to bring their tops against the hold-down below the strap, and must extend to or beyond the side edge of the plates. Grip the element near the bottom to prevent the plates flaring out while placing the element in the jar. Fill the cell to within one-half inch of the top of the jar, using electrolyte of 1.250 specific gravity. If the negative plates show signs of sulphating, but not enough to call for the special treatment mentioned above, use water instead of the electrolyte. After all of the cells have been given the same treatment and reassembled, return them to the battery box in their proper positions, so that the positive of each cell will be connected to the negative of the adjoining cell and connect temporarily by pressing the old connecting straps in place by hand.

Checking the Connections. Put the battery on charge at its finishing rate (usually about 5 amperes) and, after charging about fifteen minutes, note the voltage of each cell. This is to insure having reconnected the cells properly with regard to their polarity. If this be the case, they should all read approximately 2 volts. Any cell that reads less is likely to have been connected backward. When the cells begin to gas freely and uniformly, take a hydrometer reading of each cell and a temperature reading of one of them. Reduce the current to one-half the finishing rate. Should the temperature of the electrolyte reach 100° F., reduce the charge, or interrupt it temporarily, to prevent the cells getting any hotter. Both hydrometer and temperature readings must be taken at regular intervals, say four to six hours apart, to determine if the specific gravity is still rising or if it has reached its maximum. Continue the charge and the readings until there has been no further rise for a period of at least twelve hours. Maintain the height of the electrolyte constant by adding water after each reading. (If water were added before the reading, it would not have time to mix with the electrolyte, and the reading would not be correct.)

Should the specific gravity rise to about 1.300 in any cell, draw off the electrolyte down to the level of the tops of the plates and refill with as much water as possible without overflowing. Continue the charge, and if the specific gravity again exceeds 1.300, dump out all the electrolyte in that cell, replace it with water, and continue the charge. The charge can be considered complete only when

there has been no rise in the gravity of any of the cells during a period of at least twelve hours of continuous charging. Upon completion of the charge, the electrolyte should have its specific gravity adjusted to its proper value (1.270 to 1.280) using water or 1.300 acid, as may be necessary, and the level of the electrolyte adjusted to a uniform ½ inch above the plates.

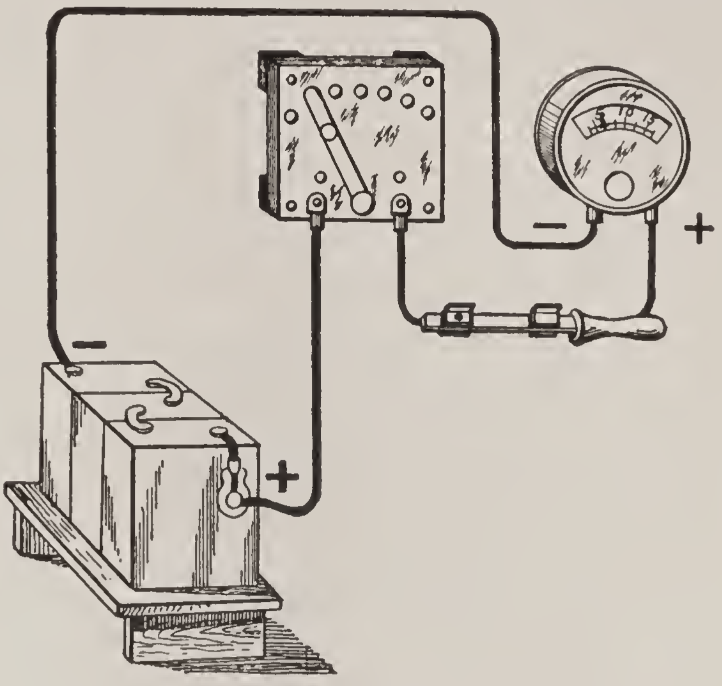


Fig. 466. Wiring Diagram for Discharging Battery through Rheostat

Discharge the battery at its normal discharge rate to determine if there are any low cells caused by defective assembly. The normal discharge rate of the battery is usually given on its name plate. To discharge the battery, the current may be passed through a rheostat, as in Fig. 466, or if no panel board of this type be available, through a water resistance, as shown in Fig. 467. The resistance of a water rheostat increases with the distance between its plates and decreases according to their proximity and to the degree of conductivity of the water itself. If the resistance is too high with the plates close together, add a little acid to the water. It will be necessary, of course, to have an ammeter in the circuit to show the rate at which the battery is discharging. In case any of the cells are low, owing to being assembled defectively or connected with their polarity reversed, as shown

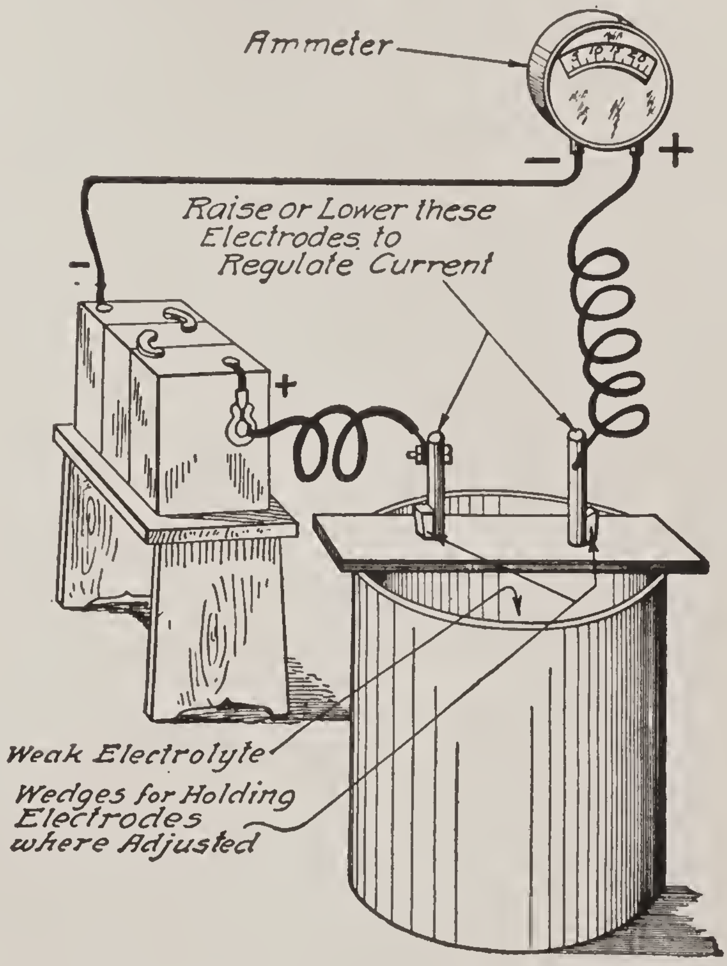


Fig. 467. Wiring Diagram for Discharging Battery through Water Resistance

by the voltmeter test (they should all register two volts or slightly over at the beginning of the discharge and should fall off slowly) such cells should be remedied at once. Recharge the battery and then remove the temporary connectors, wipe the inside edges of the jars dry, and put the rubber covers in place. Heat the sealing compound which is supplied for this purpose and apply around the edges of the covers, smoothing it down with a hot putty knife. Care must be taken not to burn the sealing compound when heating it.

Reconnecting Cells. If the old lead connecting straps have been removed carefully, they may be used again, though in many cases it will be found preferable to employ new straps. Before putting the straps in place, scrape the posts clean with a knife and clean out the eyes of the straps themselves. When the connectors have been put in place, tap them down firmly to insure good contact. Before reburning the connectors in place, test each cell with a low-reading voltmeter to make certain that the cells have been connected in the right direction, i.e., that their polarity has not been reversed. It is not sufficient to note that the voltage of each cell is correct, i.e., 2 volts per cell or over, but care must be taken also to note that it is in the right direction. With a voltmeter having a needle that moves in both directions from zero, one polarity will be evidenced by the needle moving over the scale to the right of the neutral line, while if the polarity be reversed, the needle will move to the left. One cell having the proper polarity should accordingly be tested and then, to be correct, the remaining cells should cause the needle to move in the same direction and to approximate the same voltage when the instrument leads are held to the same terminals in the same way for each. Where the voltmeter needle can move in but one direction, i.e., to the right, a change of polarity will be indicated by the needle of the instrument attempting to move to the left and, in so doing, butting up against the stop provided to prevent this. Complete the reassembly of the cells by burning the connectors together, as detailed under the head of Lead Burning.

Renewals. In many cases it will be found necessary upon overhauling a battery to renew the elements. These may be purchased either as loose plates or as groups ready to assemble in the battery. Except in garages doing a large amount of this work, it will not be advisable to buy the loose plates and burn them into groups.

The new groups should be assembled with rubber sheets and wood separators, as directed in overhauling the battery, the jars filled with fresh electrolyte of the proper specific gravity and the battery given a test charge and discharge with temporary connections. The electrolyte should be of 1.250 specific gravity, or seven parts of water to two of pure sulphuric acid by volume. If the test charge has been carried to a point where the specific gravity has ceased to rise for several hours, and the discharge shows no defectively assembled cells, the cells may be permanently connected.

Lead Burning. *Type of Outfit.* In the manufacture of storage batteries, and in garages where a large number of batteries are

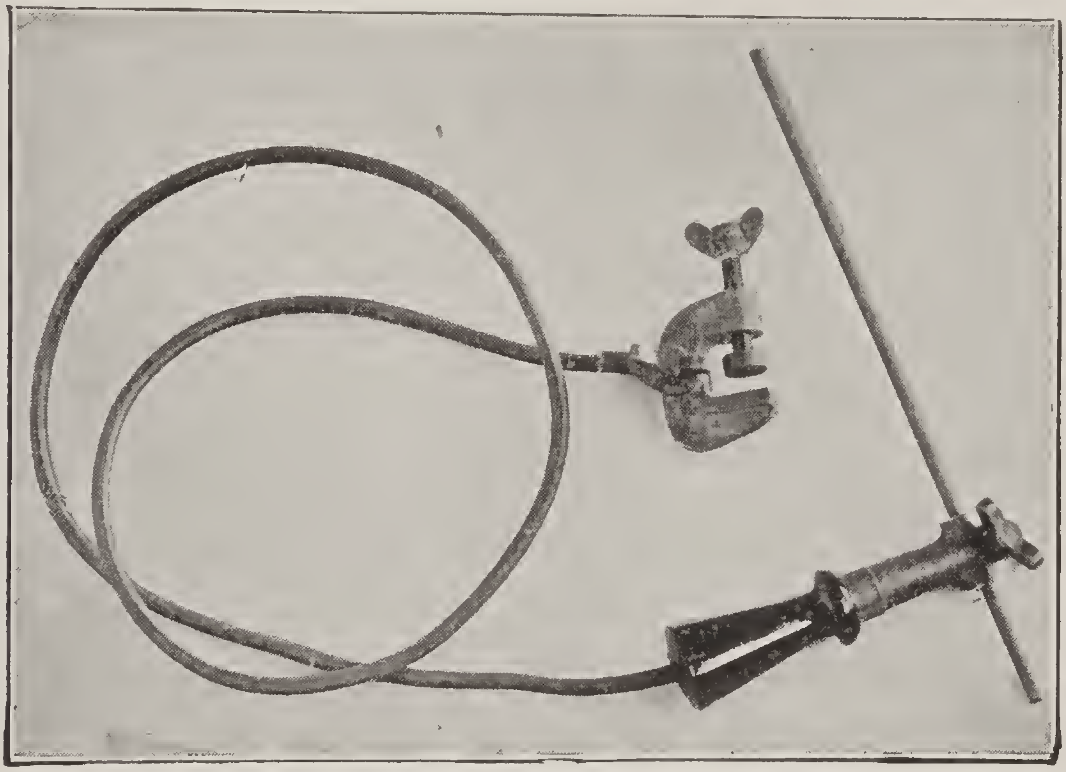


Fig. 468. Arc-Welding Outfit for Burning Connections

maintained, a hydrogen-gas apparatus is employed for this purpose. For the electric-car owner or the garage doing a comparatively small amount of battery repair work, the Electric Storage Battery Company has placed an arc lead-burning outfit on the market. This is low in first cost and, with a little practice, good results can be obtained with it. As the battery itself supplies the power necessary, the only material required is the lead in the form of a flexible strip or heavy wire. The complete outfit is illustrated in Fig. 468. At one end is the clamp for making electrical connection, while at the other is a clamp of different form having an insulated handle and holding a one-fourth inch carbon rod. The two are electrically

connected by a flexible cable. This simple outfit can be employed in two ways, the second being preferable for the beginner, at least until sufficient amount of skill has been acquired to use the arc without danger of melting the straps.

First Method of Burning. In the first method, a potential of from 28 to 30 volts (12 to 15 cells) is required. The clamp should, therefore, be fastened to the positive pole of the twelfth to the fifteenth cell away from the joint to be burned, counting toward the negative terminal of the battery. The carbon then forms the negative terminal of the circuit. Otherwise particles of carbon will be carried into the joint, as the carbon rod quickly disintegrates when it forms the positive pole. The carbon should project 3 or 4 inches from the holder. The surfaces of the parts to be burned should be scraped clean and bright, and small pieces of clean lead about $\frac{1}{4}$ to $\frac{1}{2}$ inch square provided for filling the joint. The carbon is then touched to the strap to be burned and immediately withdrawn, forming an electric arc which melts the lead very rapidly. By moving the carbon back and forth the arc is made to travel over the joint as desired, the small pieces of lead being dropped in to fill the gap as required. Owing to the high temperature generated, the work must be carried out very quickly, otherwise the whole strap is liable to melt and run.

As this method is difficult and requires practice to secure good results, the beginner should try his hand on some scrap pieces of lead before attempting to operate on a cell. Its advantages are that when properly carried out it takes but a short time to do the work, and the result is a neat and workmanlike joint. It is extremely hard on the eyes, however, and should never be attempted without wearing smoked or colored glasses, and even with this protection the eyes should be directed away from the work as much as possible.

Second Method of Burning. The second method, utilizing the hot point of the carbon rod instead of the arc, is recommended for general practice. Scrape the parts to be joined and connect the clamp between the third and fourth cells from the joint. With this method it is not necessary to determine the polarity of the carbon. The latter is simply touched to the joint and held there; on account of the heavy flow of current it rapidly becomes red and then white hot. By moving it around and always keeping it in contact with the metal, the joint can be puddled. To supply lead to fill the joint,

an ordinary lead-burning strip can be used, simply introducing the end into the puddle of molten lead, touching the hot carbon. The carbon projecting out of the holder should be only one inch, or even less, in length. After the joint has been made, it can be smoothed off by running the carbon over it a second time.

Use of Forms to Cover Joint. In joining a strap which has been cut in the center, it is best to make a form around the strap by means of a piece of asbestos sheeting soaked in water and fastened around the strap in the shape of a cup, which will prevent the lead from running down. It will be found that sheet asbestos paper is thick enough, but it should be fairly wet when applied. By this means a neat joint can be easily made. The asbestos will adhere very tightly to the metal owing to the heat, but can be removed by wetting it again. When burning a pillar post to a strap, a form may be made around the end of the strap in the same manner, though this is not necessary if reasonable care is used. Two or three pieces of $\frac{1}{16}$-inch strap iron about one inch wide, and some iron nuts about one inch square are also of service in making the joint, the strap iron to be used under the joints, and the nuts at the side or ends to confine the molten lead. Clay can also be used in place of asbestos, wetting it to a stiff paste. As the holder is liable to become so hot from constant use as to damage the insulation, besides making it uncomfortable to hold, a pail of water should be handy, and the carbon dipped into it from time to time. This will not affect its operation in any way, as the carbon becomes hot again immediately the current passes through it.

Illuminating Gas Outfit. Heretofore it has not been possible to do good work in lead burning with illuminating gas, but a special type of burner has recently been perfected by the Electric Storage Battery Company, which permits the use of illuminating gas with satisfactory results. The outfit consists of a special burning tip and mixing valve. Sufficient $\frac{5}{16}$-inch rubber hose should be provided, and the rubber should be wired firmly to the corrugated connections, Fig. 469, as the air is used at a comparatively high pressure. A supply of compressed air is necessary, the proper pressure ranging from 5 to 10 pounds, depending upon the length of hose and the size of the parts to be burned. When air from a compressor used for pumping tires is utilized for this purpose, a suitable reducing valve must be introduced

in the supply line. This outfit is designed for use with ordinary illuminating gas and cannot be employed with natural gas.

Connect the air hose to the right-hand cock and the gas hose to the left-hand cock. The leader hose, about five or six feet long, is connected to the lower pipe and to the upper end of the burning tip. When the air pressure at the source is properly adjusted, close the air cock and turn the gas cock on full. Light the gas at the tip and turn on the air. If the flame blows out, reduce the air pressure, preferably at the source. With the gas turned on full, the flame

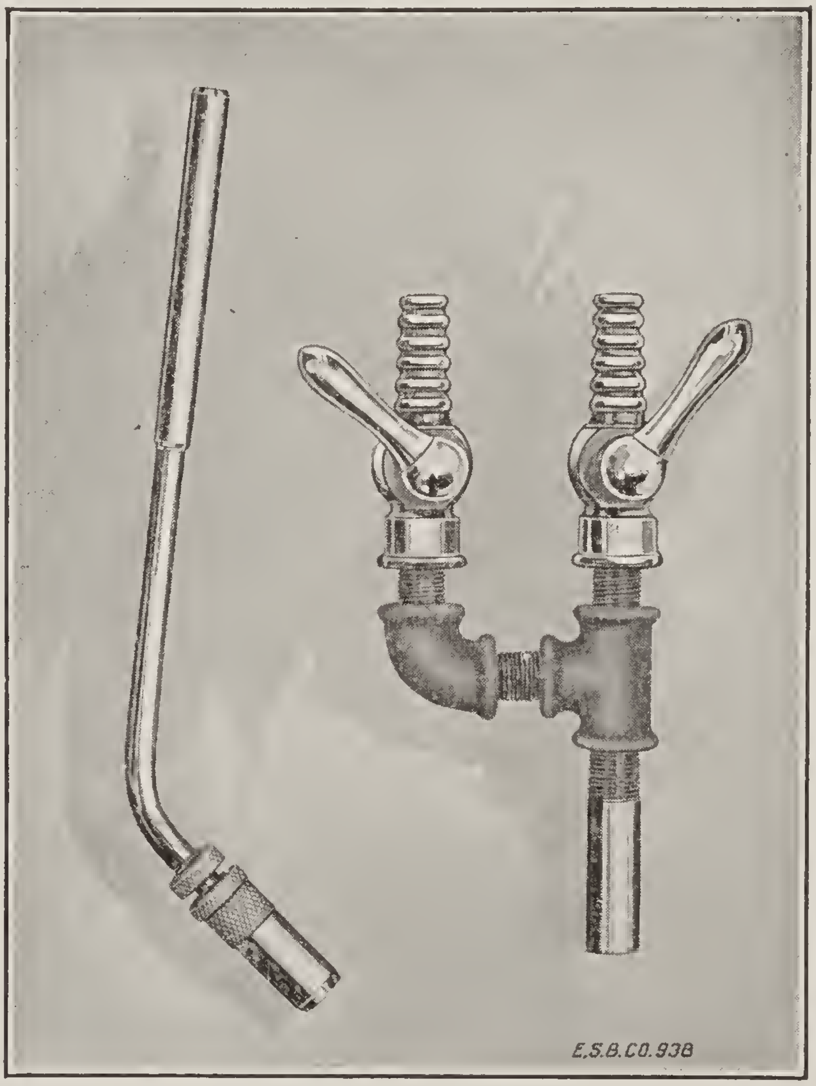


Fig. 469. Lead-Burning Outfit for Use with Illuminating Gas
Courtesy of Electric Storage Battery Company, Philadelphia, Pennsylvania

will have a ragged appearance and show a waist about $\frac{1}{2}$ inch from the end of the tip, the flame converging there and spreading out beyond. Such a flame is not for lead burning.

Slowly turn the gas off until the outer portion at the waist breaks and spreads with an inner tongue of flame issuing through the outer ring. The flame will now have a greenish color and is properly adjusted for burning. If the gas is turned off further or if too much

air is turned on, the flame assumes a blue color gradually becoming invisible and is then deficient in heating power. When properly adjusted, the hottest part of the flame is just past the end of the inner point. Do not hold the flame too close to the work when burning, as its heating effect is greatly reduced and the flame is spread so as to make control difficult. The burning tip has at its lower end an outer sleeve and lock nut; this sleeve can be taken off in case any of the holes in the tip become clogged. The position of this sleeve is adjustable, the best position varying with the pressure of the flame, and it should be determined by experiment.

Hydrogen Gas Outfit. Hydrogen gas gives a hotter flame and therefore permits of more rapid work, so that where burning is done on a large scale, it is still preferred. The essentials of such an outfit are: first, a hydrogen generator; second, a method of producing air pressure at approximately 2 pounds to the square inch; and third, the usual pipe and tips for burning. If hydrogen gas is purchased in a tank and compressed air is available, only the blowpipe, tips, and a reducing valve on the air line are necessary. This is an expensive method to purchase hydrogen, however, so that it is usually generated, and a water bottle is needed between the generator and the blowpipe to wash the gas and to prevent the flame from traveling back to the generator.

For this purpose hydrogen gas is generated by placing zinc in a sulphuric-acid solution. The generator usually employed for vehicle-battery burning requires 50 pounds of zinc, 2 gallons of sulphuric acid, and 9 gallons of water for a charge. Where no compressed-air supply is available, an air pump and an air tank for equalizing the pressure must be used. An outfit of this kind is shown in Fig. 470. In preparing the generator for use, connect up as shown in this cut, taking care that the hose from the generator is connected to the nipple of the water bottle *L*. Have the water bottle one-half to two-thirds full and immerse it in a pail of cold water up to its neck. Replace the water in the pail whenever it becomes warm. Have stop cock *N* closed. Put the required amount of zinc, which has been broken into pieces small enough to pass through the opening *C*, into the lower reservoir. Put on cap *X* and screw down with clamp *D*, being sure that the rubber drainage stopper *H* is well secured in place. Pour the proper amount of water into reservoir *A* and then

pour in the acid, taking care to avoid splashing. *Always pour the water in first.*

In running the hose from *K* to *N*, arrange it so that there will be no low points for the water of condensation to collect in; in other words, this hose should drain back at every point to the water bottle. If, however, water should collect in the hose to such an extent as to interfere with the flame and it cannot readily be drained off, kink the hose between *T* and *U* and detach it from *K;* close the stop cock at *W* and pump until a strong pressure is obtained in the tank; then close

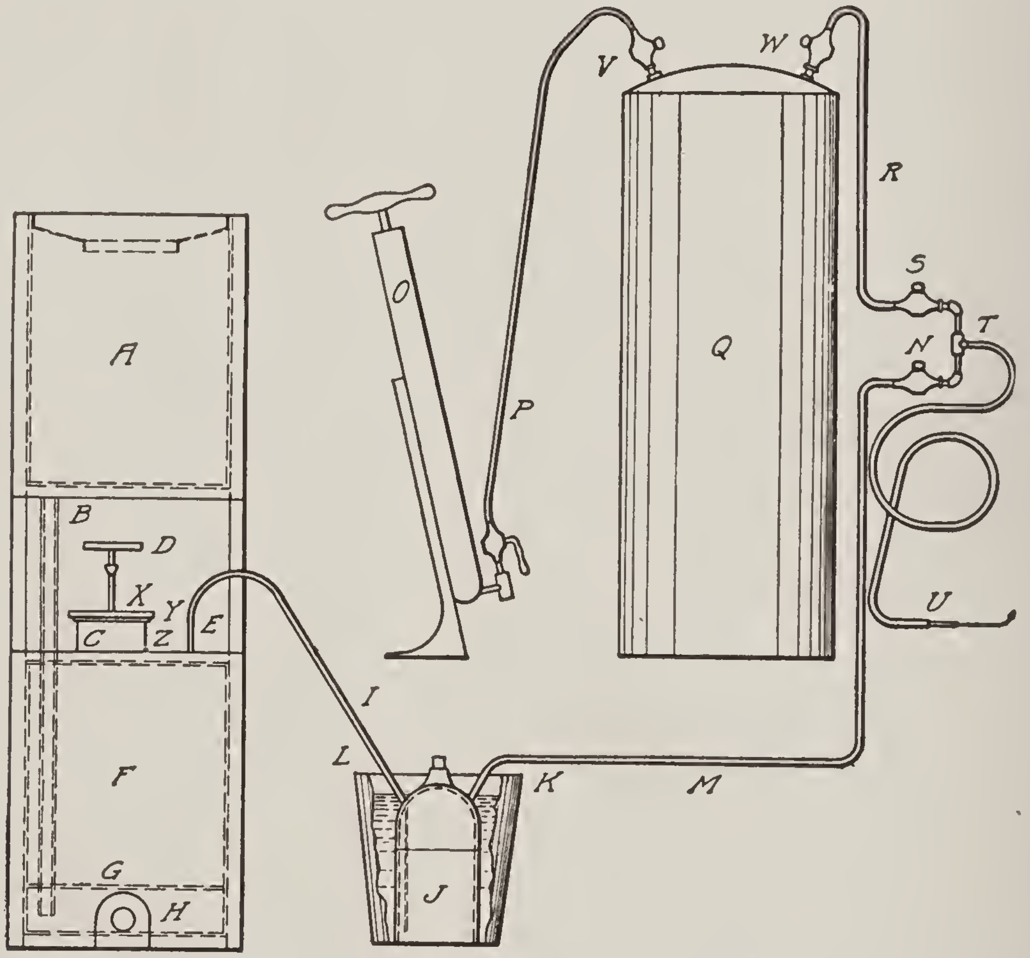


Fig. 470. Diagram of Lead-Burning Outfit, Using Hydrogen Gas

the cock at *V*, opening those at *S* and *N* and, finally, quickly open *W;* the pressure in the air tank will then force the water out of the hose. The length of the hose from *T* to *U* should be such that the mixing cocks at *S* and *N* are always within easy reach of the man handling the flame

In preparing the flame for burning, close the air cock at *S* and open *N* wide, hold a match to the gas until it lights, then add air and adjust the gas cock slowly, turning toward the closed position until the flame, when tried on a piece of lead, melts the metal and leaves a clean surface. The tip to be used depends on the work, but most vehicle-battery work is done with the medium tip. Replenish

the zinc every few days, keeping it up to the required amount. When a charge is exhausted or the generator is to be laid up for the night, the old solution should be drawn off before making up a new charge and the generator thoroughly flushed out by running water through A. The new charge should not be put in until the generator is to be used again. To empty the generator, first pull off the hose at the nipple K, then at E, and finally the rubber plug at H. Care should be taken not to allow the solution to splash on anything and not to dump the generator where the contents will damage cement, asphalt, or wood walks.

Installing New Battery. In not a few instances, it will be necessary to renew the entire battery. As received from the manufacturer, the battery is in a charged condition, i.e., it was fully charged just previous to being shipped, but it must be inspected and tested before being installed on the car. Care must be taken in unpacking it to avoid spilling any of the electrolyte. After cleaning off the packing from the tops of the cells, take out the rubber plugs and see that the electrolyte is $\frac{1}{2}$ inch over the plates. If it is uniformly or approximately below the proper level in all the cells, this is simply the loss due to evaporation. But if low in only one or two cells, this is evidently caused by loss of electrolyte. In case this loss has resulted from the case being turned over in shipment, it will be indicated by the presence of acid on the packing on top of the battery (the acid does not evaporate), and some of the electrolyte will have been lost from all the cells. Replace the amount lost by refilling the cells with electrolyte of 1.250 specific gravity, as already directed.

In case the loss of electrolyte is caused by a cracked or broken jar, the packing under the battery will be wet. Replace the broken jar as instructed in the directions under that heading and add sufficient electrolyte of 1.250 specific gravity to make up for the loss. Should it be found, after replacing the broken jar and giving the battery an equalizing charge, that the specific gravity does not reach approximately 1.275, it is due to not having replaced the same amount of acid as was spilled. To adjust this, draw off the electrolyte from the cell with the syringe and add water or 1.300 acid to bring the specific gravity to between 1.270 and 1.280.

Storing a Battery. There is an amusingly erroneous idea prevalent to some extent that the charge of a storage battery is

represented by its electrolyte; that pouring off the electrolyte takes takes the charge with it; that, in case it is desired to store a battery, all that is necessary is to pour off the electrolyte and store the empty battery and the solution separately; and when it is desired to put the battery back in commission, it is then only necessary to pour the electrolyte back into the cells and, presto! they are ready to start the engine right away. Unfortunately for this theory, the charge is in the active material of the plates and not in the electrolyte.

It is frequently necessary to allow the battery to remain idle for a considerable length of time, in which case it should be put out of commission. If the battery itself is in good condition at the time and if it may be wanted for service again at short notice, this need only consist of giving it a long equalizing charge until the specific gravity has ceased to rise for several hours, then filling the cells to the top with distilled water and putting the battery away in a handy place. It should be given a freshening charge every two weeks or, at least, as often as once a month. If it is actually to be stored, there are two ways of doing this.

One is known as the wet storage method, and the other as the dry, the one to be adopted depending upon the condition of the battery and the length of time it is to be out of commission. The wet storage method is usually applied to any battery that is to be out of commission less than a year, provided that it will not soon require repairs necessitating dismantling it. The dry storage method is used for any battery that is to be out of commission for more than a year, regardless of its condition, and it is also applied to any battery that will shortly require repairs necessitating its dismantling. It will be apparent that this last-named class includes most starter batteries after they have seen several months of service, so that the majority can be placed in dry storage when necessary to put them out of commission.

Examine the conditions of the plates and the separators and also the amount of sediment in the bottom of the jars. If it is found that there is very little sediment and the plates and separators are in sufficiently good condition to give considerable additional service, the battery may be put into wet storage by giving it an equalizing charge and covering it to exclude dust. Replace evaporation periodically to maintain the level of the electrolyte $\frac{1}{2}$ inch above the

tops of the plates. At least once every four months, charge the battery at one-half its normal finishing rate (see name plate on battery box) until all the cells have gassed continuously for at least three hours. Any cells not gassing should be examined, and the trouble remedied.

When examination shows that the battery will soon require dismantling, it should be put into dry storage. Dismantle the cells in accordance with the instructions already given. If the positive plates show much wear, they should be scrapped; if not, remove any loose particles adhering to them by passing a smooth wood paddle over the surface, but *do not wash the positive plates*. Charged negative plates will become hot in a short time when exposed to the air. They should be allowed to stand in the air until cooled.

Empty all the electrolyte out of the jars into a glass or glazed earthenware jar or a lead-lined tank and save it for giving the negative plates their final treatment before storage. Wash all the sediment out of the jars and wash the rubber separators carefully, then dry them and tie them in bundles. Place the positive groups together in pairs, put them in the jars, and store them away. Then put the negative groups together in the same way, place them in the remaining jars, and cover them with the electrolyte saved for the purpose, allowing them to stand in it for five hours, at least. Then pour off the electrolyte, which may now be discarded, and store away the jars containing the negatives. If the negative plates show any bulging of the active material, they should be subjected to the pressing treatment first, using boards and a vise, as described in a previous section. All of the jars should be well covered to exclude dust.

Make a memorandum of the amount of material required to reassemble the battery, and, when ordering this, provide for extra jars and covers, extra rubber separators, and an entire lot of wood separators with a sufficient excess to take care of breakage in handling. Unless the old connectors were carefully removed, order a new set. When a battery is put in storage, it is well to advise the owner in regard to the material necessary to reassemble, and to request at least a month's notice to procure it.

Charging from Outside Source. Theoretically at least, the starter battery on the automobile should be kept in an ideal condition. It is constantly under charge while the car is running at anything

except the lowest starting speeds and should accordingly always be fully charged. The generator is designed to take care of the storage battery and usually has sufficient capacity to light all the lamps in addition. Practice, however, does not bear out this theoretical view of the favorable conditions under which the starter battery is supposed to operate. It will be apparent at the very outset that the method of charging and discharging is not beneficial. To insure long life to a storage battery, it should be fully charged and then discharged to at least seventy-five per cent of its maximum capacity before recharging. It should never be allowed to stand discharged for any length of time. If exhausted, it should be recharged immediately. It should not be charged to half its capacity and then discharged. It should not be overcharged to the point where it continues to gas violently nor where its temperature exceeds 100° F.

All of these are things that should not be done to the storage battery, but it will take only a little experience to enable the garage man to recognize that all these are things which are constantly being done to the majority of storage batteries on gasoline automobiles. Most batteries receive treatment that reaches one extreme or the other, though it will be apparent that the middle course is almost as injurious to the battery. Either a battery is constantly kept undercharged so that it has insufficient charge to spin the engine more than once, and its operation is accordingly unsatisfactory, or it is constantly kept overcharged with the result that the hot acid makes comparatively short work of the plates, and they must be renewed in considerably less than a year of service. The mean course between these two is found in the case of the battery that is only charged to about half its capacity before being discharged again by the use of the starting motor. This treatment results in sulphating.

To keep the storage battery of the starting system in anything like efficient operating condition, it cannot be left on the running board with nothing but the generator of the starting and lighting system to charge it. Hydrometer and voltage tests will be valueless unless the conditions they indicate are remedied, and this cannot be done with the car generator as the sole source of charging current. Here is a typical instance: The battery is in good condition and it is fully charged. On a cold morning, it is drawn on intermittently

for almost fifteen minutes by the starting motor before the engine fires. As a result, it is practically discharged. The car is driven only a few miles, stopped and after a rest started again. What charge the battery received by the short run is again lost. The car is run for a little longer time and returned to the garage. The battery has received about one-fourth its normal charge. It stands this way for several days.

The weather being warmer, the engine starts in a much shorter time, but not before the starting motor has exhausted the small amount of charge in the battery. It is not run enough that day to charge the battery nor when taken out again that night, as all the lights are switched on, and under such conditions the battery receives very little current. Multiply this treatment by five or ten representing the number of days the car is driven during the month. At the end of that time, the battery no longer has sufficient charge to operate the starting motor at all and is condemned, as usual, by the car owner as being worthless. This is only one instance of many that are so similar that a few changes in detail would cover them all. No battery ever made could possibly operate efficiently under such conditions. After the car in question had been used a few days, a hydrometer test of the battery would have indicated its need of charging.

Equalizing Charges Necessary. Even where a battery receives almost 100 per cent of its normal charge before being discharged again, there will be numerous occasions on which the charge is not carried to completion. As mentioned under the head of Sulphating, that means so much acid left in the plates at the end of the charge. That acid represents lead sulphate which continues to increase in quantity as long as the acid remains in contact with the active material. To drive it out of the active material into the electrolyte, which is the function of charging, the charge must be carried to completion. This is termed an equalizing charge, and it should be given not oftener than once in two weeks, but at least once a month. To do this, it is necessary to charge the battery from an outside source, as it is seldom convenient to run the engine for the long period of time needed to complete such a charge. Except in cases where the battery is chronically overcharged, as indicated by its violent and continued gassing, it will usually be found necessary

to give it an equalizing charge once a month. The constantly overcharged condition is quite as injurious as its opposite, and it can be cured only by cutting down the output of the generator or increasing the demand upon the battery for current.

Methods of Charging. The apparatus employed for charging starter batteries will naturally vary in accordance with the number that are looked after in the garage. It may range from the makeshift consisting of a bank of lamps up to an elaborate panel board designed to provide charging connections for a dozen or more batteries at once. Where direct current is available—and only a few starter batteries need this attention—a bank of lamps in connection with a fused double-pole switch will be found to fill all the requirements. Note the charging rate (finishing) given on the name plate of the battery and make the number of lamps in accordance. A 32 c.p. in the circuit is practically the equivalent of one ampere of current entering the battery, i.e., it requires one ampere to light a lamp of this size and type (carbon filament) to incandescence. A number of standard lamp sockets should be mounted on a board, connected in multiple, and the group connected in series with the switch and the battery. (See illustration in résumé of questions and answers on the battery.) As many lamps as necessary may then be screwed into the sockets. The more current needed, the more lamps and the higher power lamps will be necessary. Tungsten lamps may be employed as well as the carbon-filament type, but as they take so much less current, lamps of higher candle power will be needed. For example, to replace a 32-c.p. carbon-filament lamp, a 100-watt tungsten lamp will be required.

Charging in Series for Economy. Where several starter batteries are to be charged at the same time, it will be found more economical to connect them in series and charge them all at once. The difference between the 110-volt potential of the lighting mains and the 6 to 8 volts needed to charge a single three-cell battery represents that much waste, as the drop in voltage has to be dissipated, through a resistance, to no purpose. In this way, any number of 6-volt storage batteries, up to twelve, can be charged from a 110-volt circuit (direct-current) with the same expenditure of current as would be required for a single battery. This is owing to the fact that, in any storage battery, the capacity of the battery is the capacity of one cell,

where all are connected in series. Consequently, it will take 10 to 15 amperes to charge one 6-volt battery from the lighting circuit, and when several more units of the same size are connected in series with it, the current consumption will still be the same, but a smaller part of the voltage will have to be wasted through a resistance.

Motor-Generator. Direct current will be found available in comparatively few places to-day, so that some means of rectifying an alternating current, in order to use it for charging batteries, will be necessary. Where quite a number of batteries are to be cared for, the motor-generator will be found to give the highest efficiency, besides proving more economical in other ways. As its name indicates, it consists of a motor wound for alternating current and fed from the supply mains of the garage, and a direct-current generator which is driven at its normal generating speed by the a.c. motor. There is no electrical connection between the two units. Electrical power in the form of an alternating current is converted into mechanical power in the a.c. motor which drives the armature of the d.c. generator and again converts it into electrical power in the form of a direct current. The first cost of a motor-generator is such that its use is usually confined to large establishments handling quite a number of batteries, though motor generators are now made in much smaller sizes than formerly.

A.C. Rectifiers. Where the amount of charging to be done does not warrant the investment in a motor-generator, a rectifier is usually employed. There are several makes of different types on the market: the chemical type, which employs lead and aluminum plates in an acid solution; the mercury-arc type, in which mercury is vaporized in a vacuum by the passage of the current; and others, in all of which the principle is the same. This consists in utilizing the current on but one part of the wave, so that the efficiency of these rectifiers ranges from 60 to 75 per cent. It is accordingly not good practice to employ them except in the smaller sizes. While the mercury-vapor rectifier is made for charging private vehicle batteries, the other types are ordinarily confined to sizes intended for charging small batteries.

A recent addition to the list that is available for this purpose is the Tungar rectifier, made by the General Electric Company. The principle on which this works is the same, but the medium is a new

one. This is a bulb exhausted of air and filled with a special gas in which a heavy tungsten-wire filament is brought to incandescence by the passage of the alternating current. This filament is very short and thick, its diameter depending upon the capacity of the rectifier, and it is placed horizontally. It constitutes the cathode of the couple. Directly opposite it, but a short distance away, is the anode of graphite in the form of a button, the lower face of which is presented to the tungsten wire. It is made in three sizes, the smallest of which has a capacity of but 2 amperes and is designed for charging the batteries of small portable lamps, such as are used by miners; and for charging ignition, call bell, burglar alarm batteries, and the like.

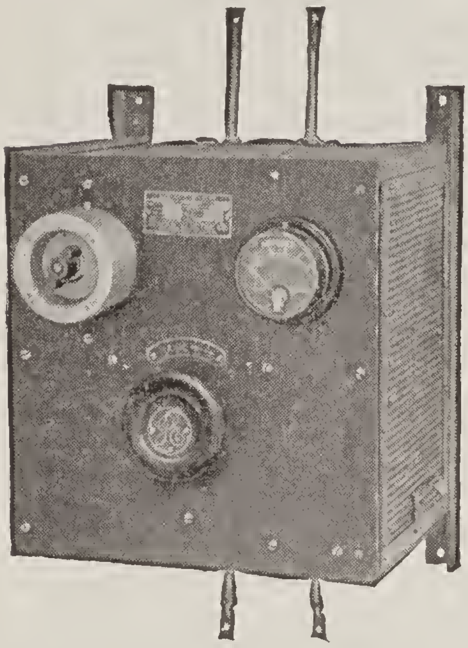


Fig. 471. Front View of Large Size G. E. Tungar Rectifier

In the larger size, as shown in Fig. 471, the bulb is mounted in an iron case, on the face of which are mounted the switch for alternating current; an ammeter on the d.c. side, showing the charge received by the battery; and a dial switch for adjusting the voltage to the number of batteries to be charged. There is a compensator with 15 taps, and the current is adjustable by steps up to 6 amperes. Anything from a single three-cell battery up to ten of such units

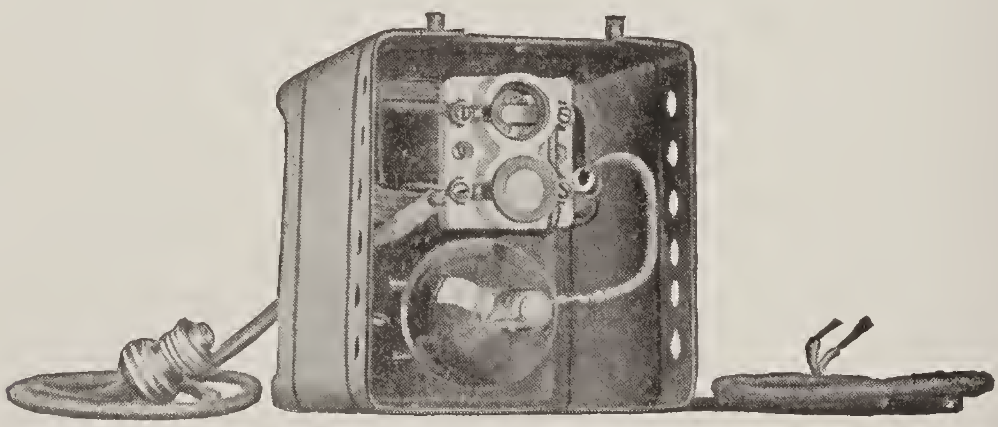


Fig. 472. Interior View of Small Size G. E. Tungar Rectifier
Courtesy of General Electric Company, Schenectady, New York

(30 cells in all) may be charged at once. The batteries must be connected in series and then it is only necessary to turn the switch of the a.c. circuit. In case the alternating-current supply should fail, the battery cannot discharge through the rectifier, and the latter

will assume its task again automatically as soon as the current comes on. This is the 6-ampere 75-volt size. It is also made in a 6-ampere 15-volt size designed for the charging of a three- or six-cell starter battery in the home garage. Fig. 472 shows an interior view of this size, illustrating the position of the converting bulb, the compensator, the reactance coil, and the fuses, while Fig. 473 illustrates the 6-ampere 75-volt size, showing the panel instrument, i.e., switch, ammeter, and regulating handle, as well as the bulb and fuses. A closer view of the bulb itself is shown in Fig. 474.

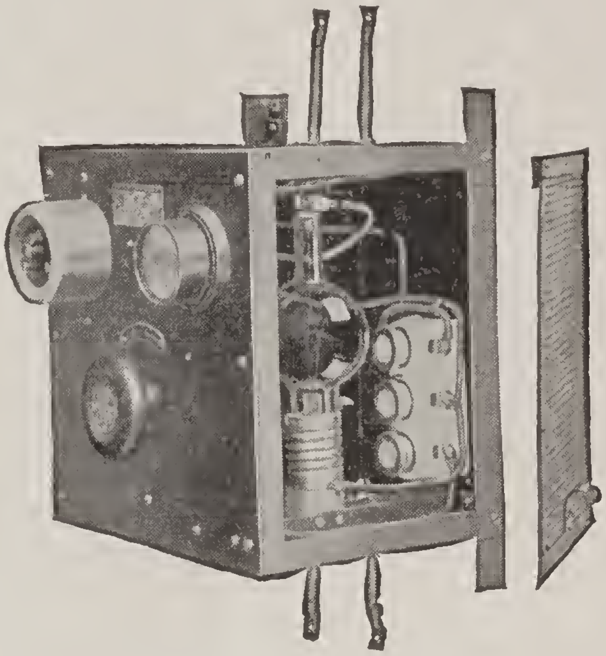


Fig. 473. Interior View of Large Size G.E. Tungar Rectifier

Care of Battery in Winter. There is a more or less general impression that special treatment must be given the storage battery during cold weather. This is probably owing to the fact that lack of attention makes itself apparent much more readily in winter than in summer because of the lower efficiency of the battery resulting from the lower temperature. The care necessary in winter does not vary in any respect from that which should be given in warm weather, except possibly that replacement of the water due to evaporation is not called for so often, but unless it is conscientiously carried out, the battery is apt to suffer to a greater extent. In speaking of low temperatures, it must be borne in mind that this always refers to the temperature of the electrolyte of the battery, and not to that of the surrounding atmosphere. The latter may be considerably below freezing, whereas the liquid in the cells may be approaching 100° F. when the battery is under charge.

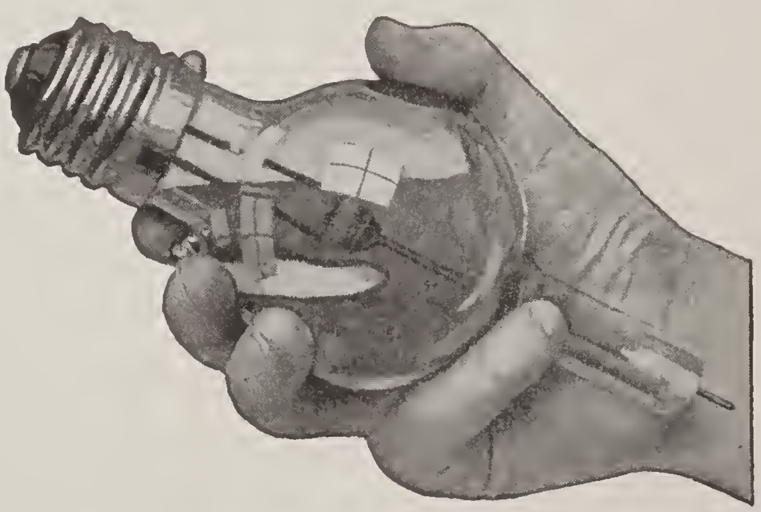


Fig. 474. Tungar Rectifying Bulb—the Heart of the Rectifier

Make the usual hydrometer and voltage tests, as described under the headings in question, and see that the battery is constantly kept more fully charged than would be necessary to render satisfactory service in warmer weather. This is important for two reasons: first, because of the greatly increased drain on the battery owing to the difficulty of starting the engine when cold; and second, because of the liability of the electrolyte to freeze if the battery is allowed to stand discharged in very cold weather. There is not the same excess supply of current available for charging the battery in winter as there is in summer, as the lights are in use during a much greater part of the time and not so much driving is likely to be done during the day. As the lamp load consumes almost the entire output of the generator in the average starting and lighting system, there is very little left for the battery when all the lamps are in use. The practice of turning on all the lights on the car—headlights, side lights spot light, and instrument lights—whether they are necessary or not, should be discouraged in winter, as it is likely to result in exhausting the battery. The instrument lights are usually in series with the tail light, and so cannot be dispensed with, but it is never necessary to have the headlights and side lights going at the same time, and this also applies to the spot light, which consumes almost as much current as one of the headlights and should be restricted to the use for which it is intended, i.e., reading signs by the roadside.

Unless the lamp load is reduced, it may be necessary to increase the charging rate of the generator during the cold months, and this is not beneficial to the battery, as it may cause severe gassing and injury to the plates when continued too long. In case the car is not driven enough to keep the battery properly charged, it may be necessary to charge it from an outside source or, if the latter be not available, to run the engine with the car idle just for this purpose. Care must be taken to prevent any danger of freezing, and the best method of doing this is to keep the battery fully charged, as when in this condition it will freeze only at very low temperatures. The more nearly discharged a battery is, the higher the temperature at which it will freeze, and freezing will ruin the cells, regardless of whether it happens to crack the jars or not.

Why Starting Is Harder in Cold Weather. The electric starting and lighting system, or rather the storage battery, which is its main-

stay, is much more severely taxed in winter than in summer for the following four reasons:

(1) The efficiency of the storage battery decreases with a decrease in temperature, because the action of the storage battery is chemical, and chemical action is dependent upon heat and, therefore, always decreases as the temperature decreases.

(2) The lower the temperature the stiffer the lubricating oil, which gums the moving parts together, adding a very considerable load to the ordinary amount of inertia which the starting motor must overcome and likewise adding to the difficulty of turning the engine past compression.

(3) Gasoline will not vaporize readily at a low temperature, so that it is necessary to turn the engine over a great many revolutions before the cylinders become sufficiently warmed from the friction and the repeated compression to create an explosive mixture. The better the mixture the more readily it will fire, and consequently a greater heat value is required in the spark to ignite it where the mixture is poor or only partly vaporized. Anything that reduces the efficiency of the storage battery likewise reduces the heat value of the ignition spark.

(4) Low heat value of the spark often makes it difficult to start an engine when cold. This lack of heat in the spark is caused by a partially discharged battery as well as the lower efficiency of the battery caused by the cold weather; also by the necessity for repeated operation of the starting motor, whereby the voltage of the battery is temporarily cut down.

Intermittent use of the starting motor with a brief period between attempts will frequently result in starting a cold engine where continued operation of the starting motor will only result in exhausting the battery to no purpose. The longer the starting motor is operated continuously the lower the voltage of the battery becomes, with a corresponding drop in the heat value of the ignition spark. Cranking intermittently a number of times has practically as great an effect in warming the cylinders and generating an explosive mixture as running for the same period (actual operating time in each case), while the brief periods of rest permit the battery to restore its normal voltage, which increases the heat value of the spark and causes the engine to fire. Both the storage battery and the remaining essentials

of the starting and lighting system are designed to give satisfactory service in cold weather, but as a very low temperature brings about conditions representing the maximum for which the system is designed, more skillful handling is necessary in winter than in summer to obtain equally good results.

To Test Rate of Discharge. If the battery terminals are removable, take off either the positive or the negative terminal, and connect the shunt of the ammeter to the terminal post and to the cable which has been removed, binding or wiring it tightly in place to insure good contact. Where the battery terminals are not easily removable, insert the shunt in the first joint in the line,

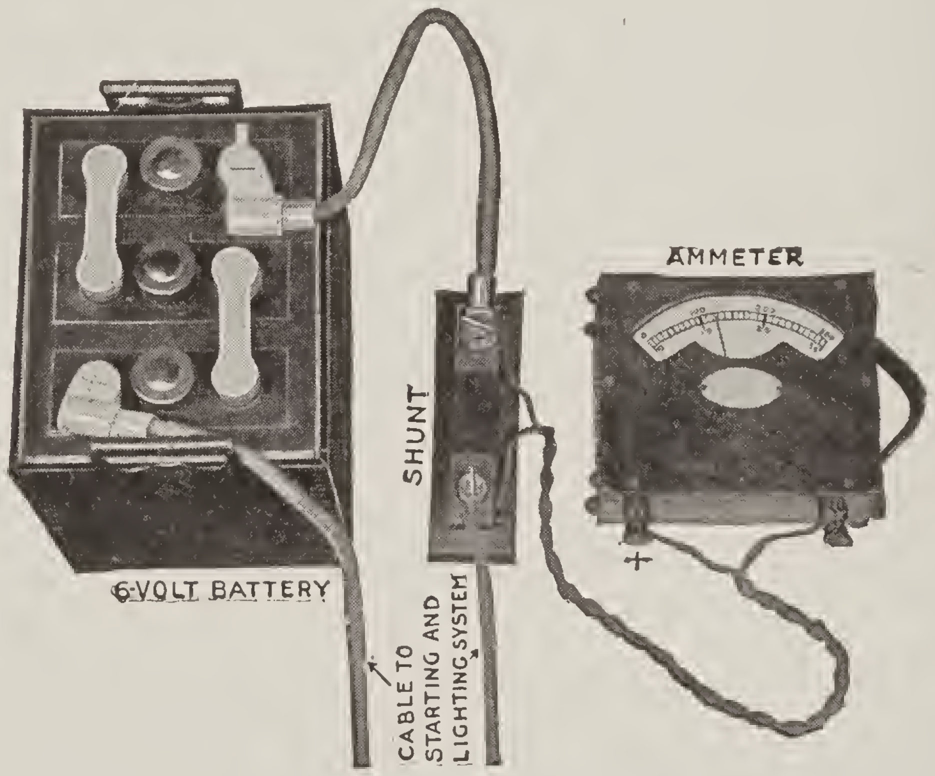


Fig. 475. Setup for Testing Rate of Discharge of Small Storage Battery
Courtesy of Prest-O-Lite Company, Indianapolis, Indiana

as shown in the illustration, Fig. 475. Then connect the ammeter terminals to the shunt. In case the instrument shows a reverse reading, reverse the connections to the shunt. When the ammeter is connected to test for discharge, the starter must never be used unless the 300-ampere shunt is in circuit, as otherwise the instrument is likely to be damaged. If a shunt of smaller capacity or a self-contained ammeter, i.e., one designed to be connected directly in the line is employed, and it is necessary to start the engine, either crank by hand or disconnect the ammeter before using the starting motor.

When the ammeter is connected to show the discharge and no lights are on, the engine being idle, no current is being used for any purpose, and the pointer of the ammeter should remain at zero. If any flow of current (discharge) is indicated, it shows that there is a ground or a short-circuit (a leak) somewhere in the system. In such a case, apply the usual tests described under the appropriate headings for locating grounds and short-circuits.

With the ammeter connected up as shown in the illustration, the discharge rate of the battery under the various loads it is called upon to carry may be checked up, and, if it proves to be excessive in any case, the trouble may be remedied. For example, with the 300-ampere shunt in the line, the amount of energy consumed by the starting motor may be checked. Without knowing how much current a certain make of starting motor should consume in turning over a given type of engine, it will naturally be impossible to make any intelligent comparisons with the result of the tests. This information, however, is readily obtainable from the manufacturer of the starting system, and it will be found advantageous to obtain details of this nature covering the various systems in general use in your locality, as it will enable you to make these tests valuable in correcting faults. While the starting loads imposed on the electric motor by different engines will vary greatly, the general nature of the load will be practically the same in all cases. When the starter switch is closed, there will be an excessive discharge rate from the battery for a few seconds, the discharge falling off very rapidly as the inertia of the engine is overcome and it begins to turn over, with a still greater drop to a comparatively small discharge the moment it takes up its cycle and begins to run under its own power.

Before undertaking such tests, see that the battery is in good condition and fully charged. Make several tests. Note in each case whether the maximum discharge at the moment of closing the switch exceeds the maximum called for by the maker of the starting system. If a great deal more current is necessary to turn the engine over than should be the case, it is an indication either that the starting motor is in need of attention or that the engine itself is unusually stiff. Atmospheric conditions will naturally have a decided effect on the result of such tests, as an engine that has stood overnight in a cold garage will be gummed up with thick lubricating oil and

will require more power to move it at first than if it had been running only a few minutes before. As a general rule, more power will always be needed in winter than in summer, unless the tests are carried out in a well-heated garage. The condition of the engine itself will also have an important bearing on the significance of the tests, as, if the engine has been overhauled recently, its main bearings may have been tightened up to a point where the engine as a whole is very stiff.

Note also whether the discharge rate falls off as quickly as it should when the engine begins to turn over rapidly. If it does not, this also is an indication of tight bearings, gummed lubricating oil, or similar causes, rendering the engine harder to turn over. In the case of a cold engine, stiffness due to the lubricating oil may be remedied by running it for ten or fifteen minutes, and a subsequent test should then agree with the manufacturer's rating. Where the discharge rate does not drop to a nominal amperage within a few seconds from the time of closing the switch, it is simply an indication that the essentials of the engine are not in the best of working order. The carburetor may not be working properly, or the ignition may be sluggish.

In case the discharge rate is very much less than that called for by the manufacturer for that particular engine, it is an indication that the starting system itself is not in the best condition. Poor connections, worn brushes, loose brush springs, a dirty switch, or some similar cause is greatly increasing the resistance in the starting circuit, thus cutting down materially the amount of current that the battery can force through it. In such circumstances, the discharge may not reach so high a rate as that called for by the manufacturer, but to effect a start, even with the engine in normally good condition, a high rate will have to be continued longer, to the correspondingly greater detriment of the battery. In other words, a great deal more current must be drawn from the battery each time the engine is started. Thus, testing the rate of discharge may be made to serve as an indication of the condition of both the starting system and the engine itself. Should it be necessary to make more than eight or ten starts to determine definitely the cause of any variation between the discharge rates shown and those that should be indicated, with everything in normally good condition, the battery should be fully

recharged before proceeding any further, as using it for this purpose when almost exhausted is very likely to damage it. Tests of this kind show also whether the efficiency of the battery has fallen off substantially or not, as indicated by its condition after making several starts in succession. When this has been done, the battery may be tested with the voltmeter and hydrometer to ascertain how far it has been discharged. The fact that after having been in service for some time a starting system will not start the engine so many times without exhausting the battery as it would when new may be due either to a loss of efficiency in the battery or to the poor condition of the other essentials of the system. In the majority of cases, however, it will be due to the condition of the battery.

By substituting the 30-ampere shunt for the 300-ampere, the load put on the battery by the lights when switched on in various combinations may be checked and compared with the manufacturer's ratings. Where the discharge rate for the lights is less than it should be, it may be due to the use of bulbs which have seen a great deal of service, the resistance of the filaments increasing with age, or other causes which place more resistance in the circuit, such as poor connections, loose or dirty switches, and the like. Tests may also be made of the ignition system where the battery is called upon to supply current to a distributor and coil by putting the 3-ampere shunt in the circuit. The amount of current required by the ignition system is very small when everything is in normal working order, usually not more than $1\frac{1}{2}$ to 2 amperes. This also can be obtained definitely from the maker of the apparatus. Any great increase in the amount of current necessary would usually indicate arcing at the contact points, which should prove to be in poor condition; a subnormal discharge would signify a great increase in the resistance as in the foregoing cases, and should be evidenced by poor ignition service.

To Test Rate of Charge. To determine the rate at which the battery is being charged (the small dash ammeters are only approximately accurate), reverse the ammeter connections and start the engine by hand. If the car is equipped with a straight 6- or 12-volt system and a dash ammeter is used, see that its reading agrees approximately with the portable ammeter. Should the variation be small, advise the owner so that he may correct his readings

accordingly when noting the instrument on the road. In case it is very large, the dash ammeter itself should be adjusted, which can frequently be done merely by bending the pointer.

With the engine running fast enough to give the maximum charging rate, which is indicated by the fact that the ammeter needle stops rising, check the charging rate shown on the portable ammeter, bearing the following in mind: In the majority of cars, the generator is regulated to charge the battery at from 10 to 15 amperes. Some are designed to charge at as low a rate as 7 amperes. Unless the proper charging rate is definitely known, whatever maximum the portable ammeter shows may usually be assumed to be correct. Where the rate is less than 7 amperes it may generally be taken for granted, however, that the battery is undercharging, and the various tests, described in detail under appropriate headings, may be applied to locate the trouble either in the generator or in the automatic cut-out. This applies where the charging rate is too high as well as where it is too low.

The charging rates mentioned above naturally apply only to a 6-volt battery, or to a battery having a greater number of cells, which is connected in series multiple so as to charge at 6 volts. In the case of a six-cell battery permanently connected in series so that it both charges and discharges at 12 volts, the above figures must be cut in half. Twelve-cell batteries are employed in some cases, but the total voltage of the battery is used only for starting, the cells being divided into four groups in series multiple so that each group of three cells charges at 6 volts.

With the generator charging at 10 to 15 amperes, turn on all the lights. If more current is being drawn from the battery than is being supplied by the generator, this will be indicated by the ammeter showing a reverse reading or discharge. It signifies that there is a short-circuit in the lighting switch or the lamps, or in the wiring between the switch and the lamps, or that additional lights, other than those furnished originally with the system, have been added, or larger candle-power bulbs substituted, thus placing too great a demand on the battery.

If the system has been out of adjustment for any length of time, it is quite likely that the battery will shortly need repairs or replacement, because charging at an excessive rate causes the plates

to buckle and break through the separators, forming an internal short-circuit, while charging at too low a rate causes a constantly discharged condition of the battery, due to more current being normally called for than is put in. This results in injurious sulphating of the plates.

In case additional equipment has been added, the entire equipment should be turned on, and the total current required should be noted when making discharge-rate tests. Where the generator cannot supply sufficient current to permit the battery to take care of this extra equipment, the battery should be charged from an outside source at regular intervals. It is poor practice to increase

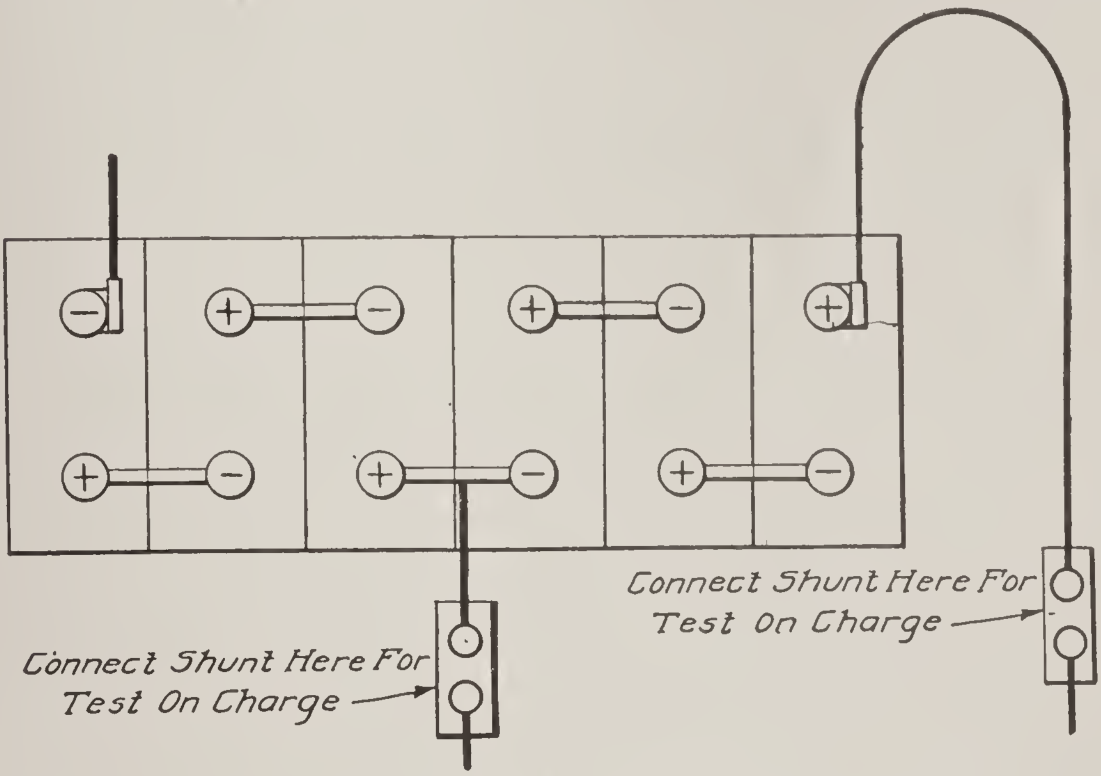


Fig. 476. Setup for Twelve-Volt Battery Wired to Charge and Discharge through Starting Motor at Twelve Volts and through Lamps at Six Volts

the charging rate of the generator, as it is likely to injure the battery through overheating. Where it is necessary to have a higher charging rate than that originally called for by the system, it is preferable to substitute a larger battery. The charging rate of the generator may then be safely increased in accordance with the demand.

In cold weather, it may be necessary to slightly increase the charging rate of the generator in order to compensate for the extra current the battery is called upon to supply. This is owing, not only to the fact that there is a much greater demand on the starting system in cold weather, but also to the fact that the battery is less efficient under winter conditions of operation.

Connections for Two-Voltage Batteries. Where the battery is of either three or six cells, all connected permanently in series, the foregoing suggestions for connecting the testing instruments apply. They must be varied, however, where tests are to be made of batteries connected in series multiple, which may be termed two-voltage batteries since they supply current at one voltage for lighting and at another for starting. In Fig. 476 is shown a battery of this type which is connected so as to charge and discharge through the starting motor at 12 volts, but which discharges at 6 volts to supply the lamps through a neutral lead in the center of the battery. The sketch indicates where to connect the ammeter shunt on charge at

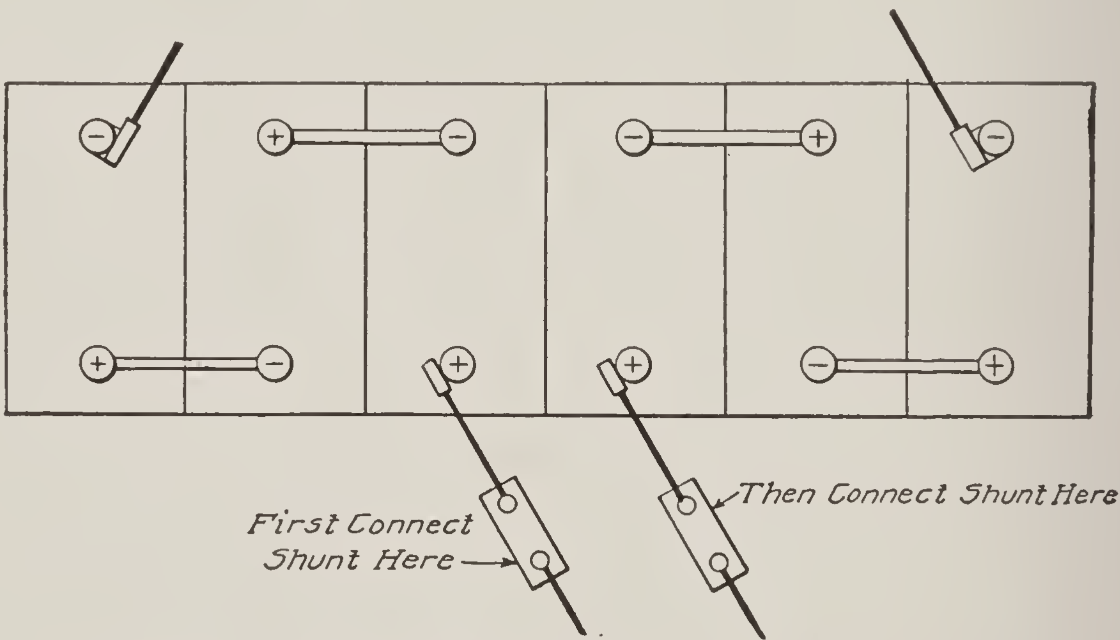


Fig. 477. Twelve-Volt Battery Connected Up to Make Two 6-Volt Batteries in Parallel

12 volts and on discharge at 6 volts. When testing the starting-motor discharge, it would be connected for 12 volts.

Test the 12-volt circuit with the engine running to get the charging rate; stop the engine, reverse the ammeter terminals and see whether there is any discharge indicating a short-circuit. Also test the discharge rate on the 6-volt circuit with the lights turned off and again with all lights on. These tests should show whether or not there is a short-circuit in the system. Before attempting to test the discharge rate of the starting motor, be certain that the 300-ampere shunt is in the circuit. A 12-volt battery will discharge only about half the current necessary to start the engine with a 6-volt battery, but no shunt smaller than the 300-ampere size can be depended upon to carry the load safely and protect the instrument.

Fig. 477 shows a 12-volt battery connected up in such a manner that it is practically two 6-volt batteries in parallel. The battery is charged at 6 volts, and both the lights and horn are supplied with current at this voltage, but the discharge through the starting motor is at 12 volts. Note the two positive cables leading to the center of the battery. To test the charging rate, the ammeter shunt should be connected first in one of these cables and then in the other, and the two readings added together to obtain the charging rate for the entire battery. The same locations for the shunt, and the same method of adding the readings also apply on discharge. Ammeter readings in the connections shown will indicate whether or not there are any short-circuits, except, of course, in the starting-motor cable.

Voltage Tests. An equally important instrument for the testing of the storage battery is the voltmeter. It is chiefly useful in showing whether a cell is short-circuited or otherwise in bad condition. Under some conditions, it indicates when the battery is practically discharged, but, like the hydrometer, it must not be relied upon alone. It should be used in conjunction with the hydrometer readings to insure accuracy. Since a variation as low as .1 (one-tenth) of a volt makes considerable difference in what the reading indicates as to the condition of the battery, it will be apparent that a cheap and inaccurate voltmeter is likely to be misleading rather than helpful. For garage use, a good reliable instrument with several connections for giving a variable range of readings should be employed. Instructions furnished with the instrument give in detail the method of using the various connections, and these instructions should be followed closely, as otherwise the voltmeter is likely to be damaged. For example, on the 3-volt scale only one cell should be tested. Attempting to test any more is likely to burn out the 3-volt coil in the meter. The total voltage of the number of cells tested must never exceed the reading of the particular scale being used at the time, as otherwise the instrument will be ruined.

Always make certain that the place on the connector selected for the contact of the testing point is clean and bright and that the contact is firm, as otherwise the reading will be misleading, since the increased resistance of a poor contact will cut down the voltage. The positive terminal of the voltmeter must be brought

in contact with the positive terminal of the battery, and the negative terminal of the voltmeter with the negative terminal of the battery. If the markings of the cell terminals are indistinct, the proper terminals may be determined by connecting the voltmeter across any one cell. Should the pointer not give any voltage reading, butting up against the stop at the left instead, the connections are wrong and should be reversed; if the instrument shows a reading for one cell, the positive terminal of the voltmeter is in contact with the positive of the cell. This test can be made with a voltmeter without any risk of short-circuiting the cell, since the voltmeter is wound to a high resistance and will pass very little current. This is not the case with an ammeter,

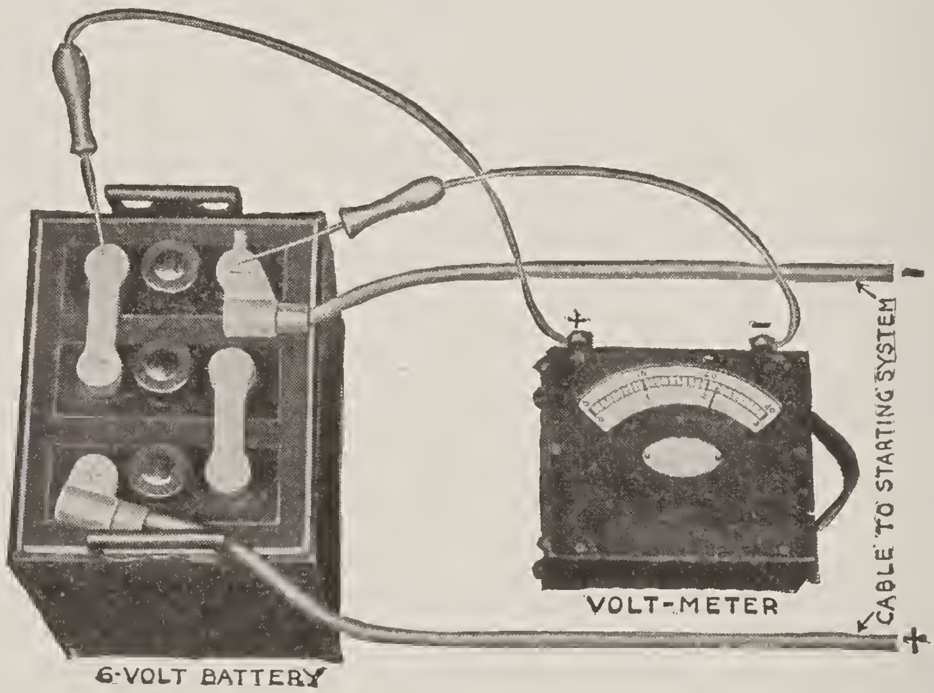


Fig. 478. Proper Setup for Testing Voltage of Batteries

however, as connecting such an instrument directly across the terminals of the battery will immediately burn out the ammeter.

Inasmuch as any cell, when idle, will show approximately 2 volts, regardless of whether it is fully charged or not, voltage readings taken when the battery is on open circuit, i.e., neither charging nor discharging, are practically valueless, *except when a cell is out of order*. Therefore, a load, such as switching on the lamps, should be put on the battery before making voltage tests. With the lights on, connect the voltmeter as explained above and test the individual cells, Fig. 478 (Prest-O-Lite). If the battery is in good condition, the voltage readings after the load has been on for about five minutes will be but slightly lower (about one-tenth of a volt) than if the battery were on open circuit. If any of the cells are completely discharged,

the voltage of these cells will drop rapidly when the load is first put on and, sometimes when a cell is out of order, even show reverse readings. Where the battery is nearly discharged, the voltage of each cell will be considerably lower than if the battery were on open circuit after the load has been on for five minutes. In the case of an electric-vehicle battery, the lights alone would not provide sufficient load for making an accurate test, so that one of the rear wheels may be jacked up and the brake set lightly until the ammeter on the dash of the car shows 50 to 70 per cent of the usual normal reading. To do this, start the motor on first speed with the brakes loose, and apply the brakes slowly until the desired load is shown by the ammeter reading. Never, under any circumstances, attempt to start with the brakes locked or on hard, as both the battery and the motor will be damaged. In the case of a starting-system battery, the lights alone are sufficient load, as they consume about 10 amperes.

To distinguish the difference between cells that are merely discharged and those that are out of order, put the battery on charge (crank the engine by hand in the case of a starter battery) and test again with the voltmeter. If the voltage does not rise to approximately 2 volts per cell within a short time, it is evidence of internal trouble which can be remedied only by dismantling the cell.

Temperature Variations in Voltage. It must be considered, in making voltage tests, that the voltage of a cold battery rises slightly above normal on discharge. The reverse is true of a really warm battery in hot weather, i.e., it will be slightly less than normal on charge and higher than normal on discharge. As explained in connection with hydrometer tests of the electrolyte, the normal temperature of the electrolyte may be regarded as 70° F., but this refers only to the temperature of the liquid itself as shown by a battery thermometer, and not to the temperature of the surrounding air. For the purposes of simple tests for condition, voltage readings on discharge are preferable, as variations in readings on charge mean little except to one experienced in the handling of storage batteries.

Joint Hydrometer and Voltmeter Tests. In making any of the joint tests described below, it is important to take into consideration the following four points:

(1) The effect of temperature on both voltage and hydrometer readings.

(2) Voltage readings should only be taken with the battery discharging, the load being proportioned to the size of the battery, as voltage readings on an idle battery in good condition indicate little or nothing.

(3) In the case of a starter battery, never attempt to use the starting motor to supply a discharge load for the battery, because the discharge rate of the battery while the starter is being used is so heavy that even in a fully charged battery in good condition it will cause the voltage to drop rapidly.

(4) The voltage of the charging current will cause the voltage of a battery in good condition to rise to normal or above the moment it is placed on charge, so that readings taken under such conditions are not a good indication of the battery's condition.

In any battery which is in good condition, the voltage of each cell at a normally low discharge rate (20 to 30 amperes for a vehicle battery or 5 to 10 amperes for a starting-system battery) will remain between 2.1 and 1.9 volts per cell until it begins to approach the discharged condition. A voltage of less than 1.9 volts per cell indicates either that the battery is nearly discharged or that it is in bad condition. The same state is also indicated when the voltage drops rapidly after the load has been on a few minutes. The joint hydrometer and voltmeter tests given below will be found to cover the majority of cases met with in actual practice.

(1) A voltage of 2 to 2.2 per cell with a hydrometer reading of 1.275 to 1.300 indicates that the battery is fully charged and in good condition.

(2) A voltage reading of less than 1.9 per cell with a hydrometer reading of 1.200 or less indicates that the battery is almost completely discharged.

(3) A voltage of 1.9 or less per cell with a hydrometer reading or 1.220 or more indicates that excess acid has been added. Under these conditions, lights will burn dimly, although the hydrometer reading alone indicates the battery to be more than half charged.

(4) Regardless of voltage—high, low or normal—any hydrometer reading of over 1.300 indicates that an excessive amount of acid has been added.

(5) Where a low voltage reading is found, as mentioned in cases 2 and 3, to determine whether the battery is in bad order or

merely discharged, stop the discharge by switching off the load, and put the battery on charge (crank the engine by hand in the case of a starter battery) and note whether the voltage of each cell promptly rises to 2 volts or more. If not, the cell is probably short-circuited or otherwise in bad condition.*

Cleaning Repair Parts. The advent of electric starting and lighting systems has added appreciably to the amount of attention required by machines in the garage, particularly as this essential is a part of the car about which its owner generally knows little. In fact, it is not overstating it to say that fully 25 per cent of all the repair work now carried on in the garage has for its object the keeping

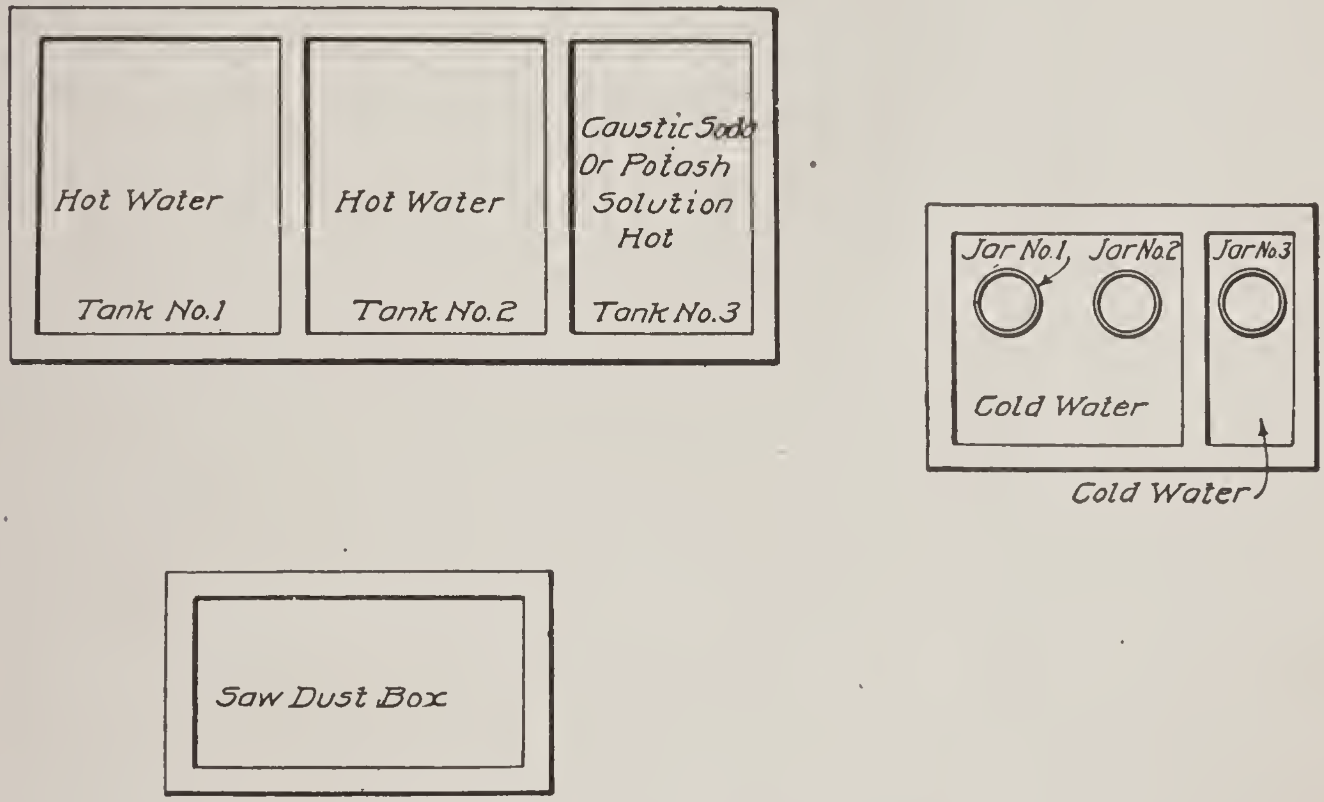


Fig. 479. Layout for Battery Cleaning Outfit

of the electrical equipment of the car in good operating condition. Where many cars are cared for and repairs to their electric systems are made as far as possible right in the garage, it will be found advisable to install a method for cleaning parts. Owing to the accumulations of dirt and grease that parts carry after having been in service for a year or more, cleaning them thoroughly before making any repairs makes it possible to detect defects which might otherwise pass unnoticed. The following instructions are reprinted through the courtesy of the makers of the Delco apparatus, and they strongly recommend that the solutions mentioned be used in the exact manner

* From instructions issued by the Prest-O-Lite Company, Indianapolis, Indiana.

directed, as they are the result of several years' experience in this work, and considerable care has been used in checking them. The sizes of the tanks given are merely indicative of what a very large repair shop would require and are comparative only. They will naturally vary with the amount of work to be done.

Cleaning Outfit. The cleaning outfit should consist of three sheet-steel tanks, Fig. 479, of suitable size (35 gallons for a large shop) mounted so that their contents may be kept heated to the desired temperature, three stone jars of approximately 15 gallons capacity, and a sawdust box. Two of the steel tanks should be equipped with overflow pipes so that they can be kept about two-thirds full at all times. These are tanks No. 1 and No. 2. They are used for clear hot water for rinsing parts after they have been cleaned. The third tank does not require a drain nor an overflow pipe and is used for the potash or caustic soda solution. This can be used for a long time without changing by simply adding a small amount of soda as the solution weakens. All three tanks are maintained at a temperature of 180° to 212° F., or approximately the boiling point.

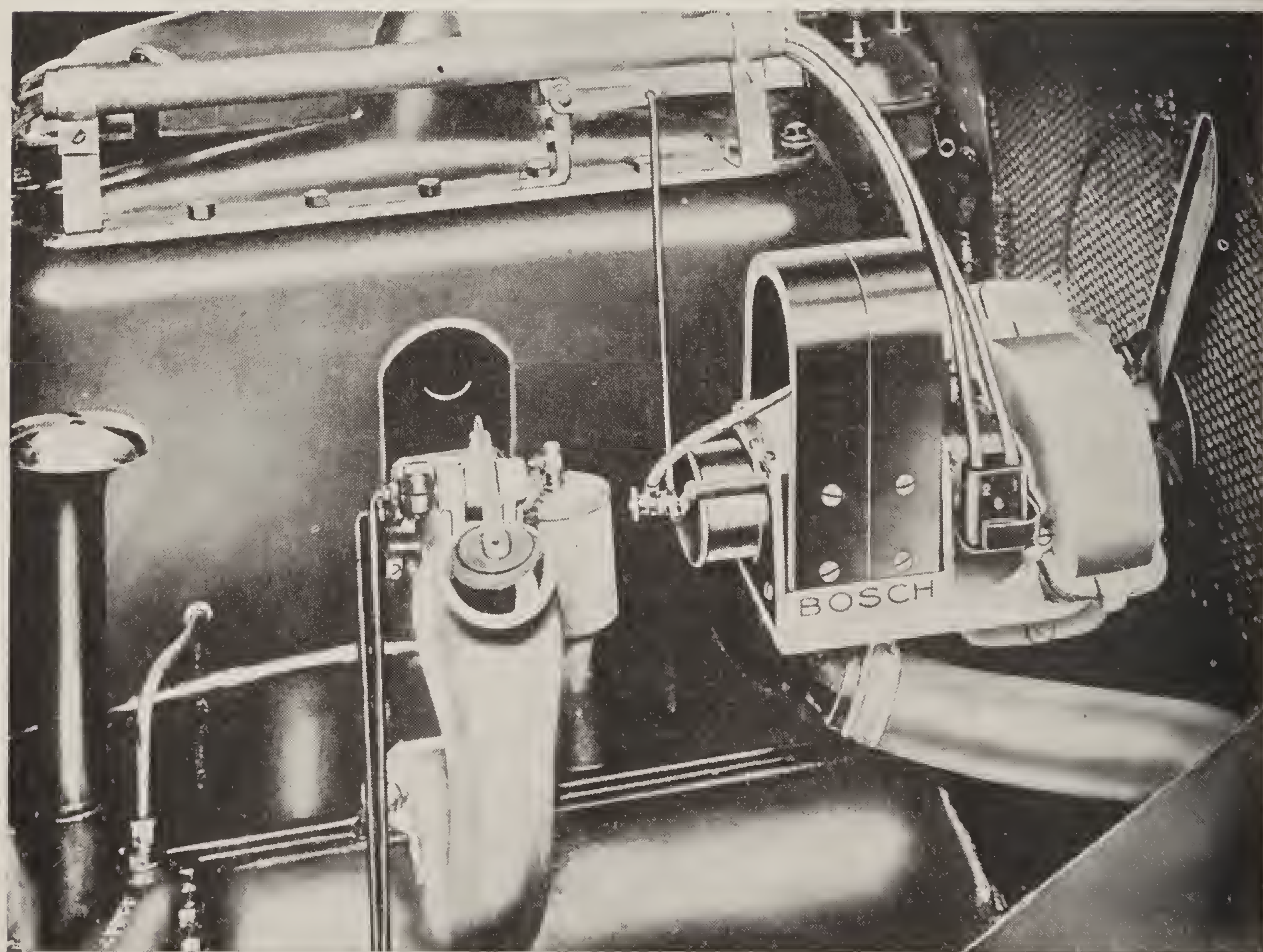
The three jars mentioned are used for the acid solutions and are referred to as jars No. 1, No. 2, and No. 3. A wood tank large enough to hold the three jars and divided into two compartments, as shown in Fig. 479, should be provided. This is important, as the parts cannot be rinsed in the same cold water after being immersed in the different acid solutions. The solutions recommended are in tanks 1 and 2, clear hot water; tank 3, a solution consisting of one pound of caustic soda per gallon of water. Jar No. 1 is filled with a solution consisting of four gallons of nitric acid, one gallon of water, and six gallons of sulphuric acid. The water is placed in the jar first, the nitric acid is added slowly, and the sulphuric acid is poured in last. This order must be strictly followed, as it is dangerous to mix a solution of these acids in any other manner. In jar No. 2, the solution is one gallon of hydrochloric acid to three gallons of water, while jar No. 3 contains a solution of one-half pound of cyanide to a gallon of water. Tank No. 2 should be used only for parts which have been in the potash solution and for no other purpose. Tank No. 1 is for general rinsing purposes.

Method of Cleaning Parts. Various metals are cleaned as follows: Steel is boiled in the potash solution until the dirt is removed, which

should require only a few minutes. The steel part is then rinsed in tank No. 2 and dried in sawdust. Vast iron parts are boiled in the potash solution to remove dirt, rinsed in tank No. 2, dipped in the acid solution in jar No. 1, rinsed thoroughly in cold clear water, dipped in the cyanide solution, rinsed again in cold clear water, then rinsed in tank No. 1 and dried in sawdust. Copper can be cleaned in the same manner. Polished aluminum should first be thoroughly washed in gasoline, rinsed in tank No. 1, dipped in the acid solution in jar No. 1, rinsed thoroughly in cold clear water, rinsed in tank No. 1, and dried in sawdust. Plain aluminum, unpolished, should be dipped in the potash solution, rinsed in tank No. 2, dipped for a few seconds in the acid solution, rinsed in tank No. 2, dipped for a few seconds in the acid solution in Jar No. 1, rinsed in cold water, then rinsed in tank No. 1, and dried in sawdust.

It will be noticed that when aluminum is put into the potash solution the metal is attacked and eaten away rapidly, so that polished parts of this metal should not be put into this solution, and any aluminum parts should not be left in for a moment longer than necessary. Where the parts are covered with caked deposits of hard grease, they should first be washed in gasoline. Aluminum parts should never be put into the potash solution unless they can be put through the acid immediately after, as the acid dip neutralizes the effect of the potash solution. Parts should only be held in the acid for a few seconds. Paint should first be removed with a good paint or varnish remover unless it is present in very small quantity, and unless the aluminum parts are to go through the potash solution. Enameled work should be washed with soap and water, dried thoroughly, and then polished with a cloth dampened with a good oil, such as Three-in-One. These cleaning methods apply only to solid parts and should never be employed on any plated pieces, as the caustic and acid would immediately strip off the plating. Such parts can be cleaned only in gasoline. It will be apparent, however, that cleaning in this manner will be found advantageous for many parts of the car that have to be repaired other than those of the electric equipment, and, in view of the increasing cost of gasoline, will be found much more economical as well as much more thorough.

TYPICAL BOSCH-RUSHMORE STARTING MOTOR
Courtesy of Bosch Magneto Company, New York City



BOSCH MAGNETO INSTALLATION ON 1916 HUPMOBILE
Courtesy of Bosch Magneto Company, New York City

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART IX

ELECTRIC STARTING AND LIGHTING SYSTEMS—(Continued)

SUMMARY OF INSTRUCTIONS ON ELECTRIC STARTING AND LIGHTING

It will be apparent from the foregoing description of the various systems that while the majority differ more or less in detail all are based on a comparatively small number of well-defined principles, and that once these are mastered their application in any system under consideration will be clear. To avoid unnecessary duplication in the instructions covering points that are common to all, general instructions have been given only in connection with one or two systems, and it will be understood that descriptions of the methods of locating short-circuits or grounds, of caring for brushes and commutator, and of testing with a portable lamp or with the volt-ammeter are equally applicable to all. The instructions given with other systems accordingly are limited to special references to the details of installation that will make it easier to locate faults in that particular system.

In order to bring the two together in such form that the particular information desired may be found instantly, a summary of all the instructions given in the preceding sections is outlined here in questions and answers.

GENERATORS

Types and Requirements

Q. How many types of generators are used in starting and lighting service on the automobile?

A. Practically all are of one type, i.e., compound-wound, but this is subdivided into other types, such as differential compound-

wound, cumulative compound-wound, and the like, that is, all lighting generators have a shunt and a series winding on their fields, but the relation of these windings to one another differs, depending upon the characteristics of the remainder of the system.

Q. What is a differential compound=wound generator?

A. One in which the series winding is reversed, i.e., wound in a direction opposite to that of the shunt winding so that its exciting effect on the field magnets opposes that of the shunt winding. The series winding is then termed a bucking coil because it bucks, or opposes, the exciting effect of the shunt winding on the field magnets as the speed increases. The series winding in this case is used simply for regulating the generator output.

Q. What is a cumulative compound=wound generator?

A. One in which the exciting effect of the series coil is added to that of the shunt coil, the series coil in this case having no connection with the regulation of the generator output.

Q. As one of the chief requirements of an efficiently operating system is the control of the generator output under widely varying speeds, how is a generator of the cumulative compound=wound type employed on the automobile?

A. The series winding is in practically an independent circuit in connection with the lamps of the car so that its exciting effect is not added to the field magnets except when the lights are switched on. This automatically increases the generator output in accordance with the number of lights turned on so that the lights have no effect on the battery charging rate, which remains the same whether the lights are on or off. An external regulator is employed to control the battery-charging rate.

Q. How does the generator differ from the motor?

A. Its essentials are all the same, i.e., it has a wound armature revolving in a magnetic field, commutator, brushes, etc., exactly the same as the generator.

Q. This being the case, why are the two not interchangeable?

A. To a certain extent they are, that is, when a current is sent through the generator from an outside source, it becomes motorized and will run as a motor. But the two are far from being interchangeable on the automobile, owing to the widely differing requirements for which they are designed. The generator is wound to produce a cur-

rent seldom exceeding a value of 20 amperes while being driven over a wide range of speeds, and it is in constant operation. The starting motor, on the other hand, is designed to utilize an extremely heavy current, ranging up to 300 amperes or more at the moment of starting and is only used for very short periods.

Q. How are these widely varying requirements reconciled in the single=unit type, in which both the generator and the motor are combined in one machine?

A. The machine is practically two units in one, i.e., there are two totally different windings on the same magnet cores, a fine winding with shunt fields for the generator, and a very heavy simple series winding for the motor end. In some cases, as in the Delco, the different windings on the armature are brought out to independent commutators. While combined on one set of magnet cores, there is no connection whatever between the two windings in such a machine, so that when operating as a generator the motor windings are dead, and the reverse is true when being used as a starting motor.

Q. What are the characteristics of the single=unit type of machine which is simply placed in circuit with the battery by a hand=operated switch when starting and left in that relation as long as the engine is running?

A. This is a variable-potential type in which the relation that it bears to the battery and to the engine is entirely dependent upon the speed of the engine, that is, the speed at which the machine is driven. When the switch is closed, current from the battery operates the machine as a starting motor; as soon as the engine starts and attains a certain speed, the voltage of the machine overcomes that of the battery, the direction of current flow is reversed, and the battery begins to charge. Whenever the driving speed falls below a certain point, there is another reversal, and the generator once more becomes a motor until the engine speed increases.

Loss of Capacity

Q. What are the chief causes for the falling off in output of the generator?

A. In about the order of the frequency of their occurrence, these are as follows: dirty or worn commutator; worn brushes making poor contact; dirty or loose connections causing extra resistance

at generator, regulator, cut-out, ground, or battery terminals; failure of cut-out to operate at proper voltage; worn or pitted contacts in regulator or cut-out; loose connections at brush holders; short-circuited coils in the armature; some of the armature-coil connections broken away from the commutator; short-circuited bars in the commutator.

Q. How can the generator output be tested?

A. The simplest method is to switch on all the lamps with the engine idle. Start the engine and speed up to equivalent of 15 miles per hour. The lights should brighten very perceptibly, the test being made indoors in the daytime with the lights directed against a dark wall, or preferably at night. A more accurate test can be made with the portable volt-ammeter, using the 30-ampere shunt. Most generators have an average current output of 10 to 12 amperes, but the normal output as given by the maker should be checked before making the test. Generators having a constant-voltage control will show a greatly increased output if the battery charge is low, running up to 20 amperes or over. On such machines, the condition of the battery should be checked either with the hydrometer or with the voltmeter before making the test. The charging current should be 10 to 12 amperes with a fully charged battery, and more in proportion when only partly charged.

Q. What other simple method is there of determining quickly whether the generator is producing its normal output or not?

A. On generators having an accessibly located field fuse (there are several makes) lift this fuse out and, with the engine running at a speed equivalent to 10 miles per hour or more, touch the fuse terminals lightly to the clips. If the machine is generating properly, there will be a bright hot spark. Should no spark appear, replace the fuse and bridge the terminals with a pair of pliers by touching the jaws to the fuse clips; if a spark appears, the fuse has blown. Before replacing with a new fuse, find the short-circuit or other cause.

Q. Granting that the fuse has not blown, that the cut-out, regulator, and wiring are all in good condition, and still the generator does not produce any current, what is likely to be the cause?

A. One of the brushes may not be touching the commutator, a brush connection may have broken, or carbon dust may have short-circuited the armature or field windings. Test for short-circuits.

Q. If the machine is generating current, and the auxiliary devices and wiring are in good condition, but the battery does not charge, what is the cause?

A. Short-circuit in the battery due to active material having been forced out of the plates, or accumulation of sediment touching plates at their lower ends. (See Battery Instructions.)

Q. Is the regulator ever responsible for a falling off in the current or for generation of excessive current?

A. Yes. Any irregularity in the operation of the regulator will affect the output of the generator.

Q. How can this be overcome?

A. This will depend upon the type of regulation employed (see Regulation). Where the method of regulation is inherent, i.e., forming part of the construction of the generator itself, such as the third-brush method, or a bucking coil, it may be remedied by cleaning and seating the brush properly or by testing the bucking-coil winding to see if its connections are tight and clean, or if it is short-circuited (see Windings). If cleaning and sanding-in the brush do not cause the generator to produce its normal output, the brush itself may be adjusted by shifting its location. Moving it backward or against the direction of rotation of the commutator will reduce the output; moving it forward or in the direction of rotation will increase the output. This refers specifically to the Delco regulation already described. To adjust properly, the portable ammeter should be put in circuit, and the effect on the reading noted as the brush is moved, clamping it back in place when the proper point is found. The brush should then be sanded-in to the commutator, as it will not have a good bearing if its original location has been disturbed.

Methods of Regulation

Q. Why is it necessary to control the output of the generator?

A. As explained in the section on electric generators, the amount of current produced depends upon the excitation of the fields, and the faster the armature revolves before the pole faces of the field magnets, the greater the amount of current that is sent through the windings of the magnets. As the speed of the automobile engine varies between such extremely wide limits, it will readily be seen that

it may rise to a point where this increase in the field excitation will cause so much current to be generated that the armature windings will be literally burned up. This happened very frequently in the early attempts to produce a lighting dynamo for automobile service. Regardless of how fast the generator may be driven, it is essential that its current output does not exceed a certain safe limit.

Q. What is the usual safe limit in the majority of generators?

A. Most automobile lighting-system generators are designed to produce 10 to 15 amperes at a normal speed, i.e., sufficient to light all the lamps and still provide a slight excess for charging the battery. No matter how fast its armature revolves, it must not exceed this by more than ten to twenty-five per cent, as a rule, this being well within its factor of safety. In some instances, where a voltage system of regulation is employed, the output of the generator depends upon the condition of charge of the battery. If the battery is practically discharged, the generator will charge the battery at a rate of twenty amperes or over. As the charge proceeds, the battery voltage increases and the resistance is increased correspondingly, thus cutting down the amount of current that the generator can force into the battery.

Q. How is the current generated kept from exceeding this safe limit?

A. Mechanical methods were employed at first, a centrifugal governor being used to operate a slipping clutch. The generator was driven through this clutch, and the speed at which the armature revolved depended upon the engagement of the clutch; at low speeds both shafts would turn at the same rate. As the driving-shaft speed increased, the governor decreased the pressure on the clutch spring, and the clutch faces slipped on one another, so that the driven shaft turned proportionately slower than the driving shaft. The earliest types of governors, employed about 1903 to 1905, were not successful, but about 1908 a type was developed that worked effectively on thousands of cars. It has since been superseded by electrical methods of regulation, and practically all of those now in use are electrically operated.

Q. How many electrical methods of regulating the amount of current generated are in general use?

A. So far as their principle goes, practically all are the same.

They depend upon weakening the excitation of the fields of the generator to cut down the output. It is in the methods of accomplishing this that they differ. In the latter respect they may be divided into two general classes: those that are inherent in the design of the machine, i.e., the regulating device is actually a part of the machine itself; and those in which an external regulator is employed. Those most commonly employed are, in the first class, the bucking-coil winding and the third-brush method; in the second, an external regulator is usually combined with the battery cut-out and designed to keep either the voltage or the current at a uniform value, usually the voltage.

Q. What is a bucking=coil winding, and why is it so called?

A. We have seen that in a series-wound machine all of the current generated in the armature passes through the field windings and energizes the field magnets; in the shunt-wound machine the wires carry only a part of the current which is proportional to the resistance that the shunt winding of the fields bears to the resistance of the outside circuit. As this outside resistance (the load) increases, more current will be diverted through the path of lesser resistance, or the shunt-wound field, and the output of the machine will increase accordingly. In the compound-wound machine, the relation of the series to the shunt winding is such that it is called upon chiefly to help carry any extra load. In other words, as the demands upon the machine increase, the series winding adds its energizing effect to that of the shunt coil. A generator with a bucking-coil winding is a compound-wound machine, but the series winding is in *the opposite direction* from that of the shunt winding. Consequently, instead of adding to the field excitation caused by the latter, it *opposes or bucks* it, and the more current there is produced in the shunt field by the rise in speed, the more the series winding, or bucking coil, tends to neutralize this excess, thus keeping the amount of magnetic effect produced in the field poles practically uniform, regardless of the speed.

Q. What is the third=brush method of regulation?

A. In a conventional shunt-wound generator, the field windings are directly in shunt with the armature through the brushes; hence, a certain proportion of all the current induced in the armature windings will find its way through the field magnet windings, in proportion to their relative resistance to the outside circuit at the time. Where a

third brush is employed, the main brushes are not in shunt with the fields, and they are not depended upon to supply the exciting current for the latter. The third brush instead is used for this purpose. As is well known, the output of a generator depends very largely upon the position of its brushes. In the immediate vicinity of the proper location for a brush, there is a short zone of maximum intensity. As we get away from this toward the next brush, it decreases until at a point midway between the two there is a neutral zone. The third brush is accordingly placed between the two main brushes, and its distance from the nearest main brush determines the amount of current that it diverts from the armature to the field windings. See illustration of Delco generator in section on Methods of Regulation. This method has the advantage of supplying a strong shunt field at low speeds. As the speed increases, the voltage applied to the shunt field decreases, even though that between the two main brushes may have increased.

Regulators

Q. What is a regulator, and what is its purpose?

A. It is an instrument somewhat similar to a battery cut-out, and its purpose is to regulate the output of the generator in order that the latter may not exceed safe limits at high speeds. The regulator is usually combined with the cut-out.

Q. How does the constant=voltage type of regulator operate?

A. The instrument consists of a magnet winding and a pivoted armature, normally held open by a spring and a resistance unit. The winding of the magnet has sufficient resistance to prevent the core becoming energized to a degree where it will attract the armature, unless the voltage exceeds the safe limit determined for the circuit. The voltage increases with the speed of the generator, so that when the latter is driven too fast the attraction of the magnet core for the armature becomes sufficient to overcome the pull of the spring which normally holds the contacts apart. (See description of Bijur voltage regulator.) When the contacts come together, the field circuit of the generator is shunted through the resistance unit; this cuts down the amount of current energizing the fields, the voltage falls off, and the contacts again separate. Unless the speed of the generator is decreased, this action is rapidly repeated, so that the regulator arma-

ture vibrates at a high speed as long as the voltage is sufficiently high to energize the magnet.

Q. What is the principle on which this type of regulator operates?

A. The principle that in a circuit having considerable self-induction the amount of current which may be sent through the circuit will decrease if the current be pulsating instead of steady. Every time the contacts of the regulator open, a pulsation, or surge, of current is sent through the field windings of the generator; when they close because of the higher voltage, the current is shunted through the resistance unit, thus cutting it down. The decrease in the amount of current is in proportion to the number of pulsations per minute, i.e., the rapidity with which the vibrating contact operates. The circuit having considerable self-induction is that of the field winding of the generator, owing to its heavy iron core. (See Induction.)

Q. What is the constant-current type of regulator, and how does it differ from the constant-voltage, or potential, type?

A. It consists of an electromagnet and a spring-controlled pivoted armature, so that it is of practically the same construction as the constant-potential type, but it is connected in circuit with the armature of the generator and it is wound to operate under the influence of the current rather than the voltage. Consequently, the pivoted armature is attracted, opening the circuit when the current exceeds a certain predetermined value, usually 10 amperes. In operation, the armature vibrates the same as in the voltage regulator, but the condition of the charge of the battery has no effect on it, so that when set to limit the current to 10 amperes, it will always charge the battery at approximately that rate regardless of the condition of the battery. The only practical difference is that it is wound to actuate under the influence of changes in the current flow and is connected in the armature circuit, whereas the constant-potential regulator is influenced by variations in the voltage and is connected in the field circuit of the generator. The latter has the advantage of charging the battery at a higher rate when the charge is most needed.

Q. What other forms of regulators are employed on lighting generators?

A. The foregoing comprise practically all of the principles

employed, but the regulators differ more or less in design and operation. For example, in the Bosch-Rushmore generator, a bucking coil is employed in connection with what is termed a ballast resistor, or resistance unit. This is of iron wire, and it is based on the fact that resistance increases very rapidly with the temperature. The size of the wire is such that it allows 10 amperes to flow without undue heating, so that its resistance is practically unchanged; above this point it heats rapidly and increases in resistance so greatly that all excess current is shunted through the bucking coil. In the Splitdorf generator, the regulator is built in, projections of the pole pieces of the field being utilized in connection with special windings, instead of an independent electromagnet as in the Ward-Leonard and the Bijur. In the U.S.L. generator of the inherently regulated type, regulation is accomplished by the combination of a Gramme ring armature, a special arrangement of connections and of the field windings, and the use of only a part of the fields and armature for generating current. The regulation obtained is based on armature reaction and is similar in effect to the third-brush method. The U.S.L. external type of regulator cuts into the generator field circuit a variable resistance consisting of an adjustable carbon pile. In the Adlake regulator, which is of the constant-potential type, a solenoid operates a switch over the contacts of a variable resistance. The plunger of the solenoid is counterbalanced by a weight, which must be raised to operate the switch. It is adjustable by increasing the weight of this counterbalance.

Q. What attention does the regulation of the generator require?

A. This will depend upon the method employed in each case. Where an external regulator is employed, whether of the constant-potential or the constant-current type, the attention required is practically the same as in the case of the battery cut-out. See that the points are not sticking, and when badly burned or pitted, smooth and true up, taking off as little of the contact point as possible to effect this. When the points have become so badly pitted that this cannot be done, new parts will be necessary.

With the third-brush method, the attention required by this brush is the same as that which must be given the other brushes, i.e., sanding-in at intervals and replacement when worn too short to permit the spring to hold the brush firmly against the commutator.

Where the generator fails to produce sufficient current to keep the battery charged, all other parts of the system being in good condition and the car driven long enough in daylight to charge the battery under normal conditions, the position of the third brush may be shifted to increase the output. Care must be taken not to let it come in contact with the main brush. (See Delco instructions.) In the case of a bucking-coil winding, no attention is necessary, as this is an integral part of the machine itself. As the Splitdorf regulator has moving contact points, the attention necessary is the same as that required for an external regulator of this type. Special regulators, such as the U.S.L. external type, require attention covered by the maker's instructions. (See U.S.L. system.)

Q. When the generator fails to keep the battery charged properly, a normal amount of daylight driving being given the car, is the fault most likely to be found in the regulator?

A. No. It is much more likely to be caused by a dirty commutator, worn brushes, loose connections, or some similar cause which inserts extra resistance in the charging circuit. The movement of the regulator armature is very slight, and the current handled by the contact points is small, so that it will seldom be the cause of the trouble. Other causes, such as those above enumerated, should always be sought first. (See instructions under Generator.)

Windings

Q. Are faults in the generator windings frequent?

A. They constitute one of the least frequent sources of trouble with the machine.

Q. What is likely to cause them?

A. Dousing the machine with water is likely to be one of the most frequent causes of short-circuits or grounds in the generator windings. All electrical machinery is intended to be kept dry. Except where provided with a field fuse, running the generator when disconnected from the battery or with the battery removed from the car is another cause. Excessive speed, in some instances, may generate sufficient centrifugal force to lift the armature coils out of their slots so that the insulation becomes abraded by rubbing against the pole pieces, but this is very unusual. In rare instances, a hard kink left in the wire when winding may crystallize the metal

and make it break at that point, due to the vibration. Unless cleaned out at intervals, fine carbon dust from the wear of the brushes may accumulate in the interstices of the windings, and, when aggravated by moisture, this is apt to cause short-circuits.

Q. What are the usual indications of such faults?

A. With a short-circuited generator coil (armature), all other parts of the apparatus and circuits being in good condition, the charging rate will be lower than normal. The ammeter needle will vibrate violently when the engine is running at low speeds, and two or more adjacent commutator bars will burn and blacken. With an open armature coil (broken wire), the indications will be practically the same, and there will be severe sparking at the brushes, causing serious burning of the commutator bar corresponding to the open coil. A grounded armature coil will give the same general indications, and if the machine is a single-unit type, the cranking ability of the starting motor will be seriously impaired. The ammeter, however, will not vibrate as in the former cases. There will be practically no charge from the generator, and the battery will be discharged very rapidly by the starting motor.

In a single-unit machine, when the windings of the generator and the starting motor become interconnected, the indications will be practically the same as those of a grounded armature coil. If the motor windings of a single-unit machine become grounded, there will be an excessive discharge from the battery, while the motor will develop but little power.

Q. How may such faults be located?

A. With the aid of the testing-lamp outfit. Remove the brushes (when replacing them later, be sure to put each brush back in the holder from which it was taken), or the brushes may be insulated from the commutator by placing paper under them. For a grounded coil, place one test point on the commutator and the other on the frame; if grounded, the lamp will light. For interconnected motor and generator windings in a single-unit machine having two commutators, insulate the brushes as mentioned and place the test points one on each commutator. The light will burn if the two windings are connected. For a grounded-motor winding, test from the motor commutator to the frame; the light should not burn if the insulation is all right. For a break or open circuit

in the field winding, touch the terminals of the latter with the test points, the commutator being insulated or the armature removed. The lamp should light. For a blown field fuse on machines so equipped, place the points on the clips; if the fuse is intact, the lamp will light.

Q. Are these tests conclusive?

A. No. They will indicate any of the faults mentioned, but they will not reveal an internal short-circuit in the windings, which cuts some of the armature or field turns out of action but does not break the circuit as a whole. Such a short-circuit reduces the output of the generator and can be determined definitely only by measuring the resistance of the windings. This requires special and expensive testing instruments, such as the Wheatstone bridge, so that where all other tests fail to reveal the cause of a falling off in the output of the generator, it should be sent to the maker for inspection.

Commutator and Brushes

Q. What does a blackened and dirty commutator indicate?

A. Sparking at the brushes or an accumulation of carbon dust due to putting lubricant on the commutator.

Q. What is the cause of sparking at the brushes?

A. Poor brush contact, due to worn brushes; brush-holder springs too loose, so that brushes are not held firmly against the commutator; excessive vibration, which may be due to a bent shaft, an unbalanced gear pinion, or improper mounting; using too much oil, or using grease in the ball bearings, which gets on the commutator and, acting as a solvent for the binder of the carbon, forms a pasty mass which prevents proper brush contact; worn or roughened commutator on which the mica needs undercutting; overload due to failure of regulator or to grounded coils in armature.

Q. What is the remedy for sparking?

A. Clean the commutator with fine sandpaper and sand-in the brushes to a true bearing on the commutator as directed in the Delco instructions. See that the brush springs have sufficient tension to keep the brushes firmly pressed against the commutator when the machine is running. If the mica protrudes above the commutator bars, it must be undercut as directed, and the commutator smoothed down again after the operation to remove any burrs.

Q. Why do some commutators need undercutting and others not?

A. Undercutting is required only on machines equipped with brushes that are softer than the mica. Copper-carbon brushes, as employed on starting motors to reduce the brush resistance, are hard enough to keep the mica worn down with the copper of the commutator itself.

Q. If, after smoothing off and undercutting the mica, the commutator still has an uneven and irregular surface, what is the remedy?

A. The armature should be removed from the machine, and the commutator trued up in the lathe, taking as light a cut as possible consistent with obtaining a true round and smooth surface.

Q. How can excessive commutator wear be prevented?

A. Inspect at regular intervals and on the first sign of sparking smooth up the surface and sand-in the brushes. Keep the commutator clean and do not permit carbon dust or oil to accumulate in the commutator and brush housing. Never replace brushes or brush springs with any but those supplied by the manufacturer for that particular model. The machine will work with any old brush and any old spring that fits, but they will prove detrimental to its operation in a comparatively short time, and its *working* under such conditions will never be satisfactory.

Q. Is discoloration of the commutator ever caused by anything else than sparking?

A. Not actual discoloration which requires cleaning, but the normal operation of the machine produces a purplish blue tinge on the bars, which is sometimes mistaken for discoloration by the inexperienced. This color, in connection with a high polish of the metal, indicates that the commutator is in the best of condition. Once the commutator takes on this high polish, it will operate for long periods without other attention than the removal of dirt by wiping with a clean rag. Sanding to remove this purple tinge is a mistake, as it only destroys the polish without having any beneficial effect.

Q. Is it necessary to lubricate the surface of the commutator?

A. No. The brushes employed are usually of what are termed a self-lubricating type and require no attention in this respect.

Q. Will any harm result from putting light grease, vaseline, or lubricating oil on the surface of the commutator?

A. As all lubricants are insulators to a greater or less extent, the efficiency of the machine will be reduced and, as the voltage is very low, but a slight falling off is necessary to represent a very substantial percentage of the maximum. The use of lubricant of any nature on the commutator also has another harmful effect in that it collects the carbon dust resulting from the wear of the brushes, causing it to lodge against them as well as between the commutator bars.

Q. Why should particular care be taken to remove all carbon dust from the commutator housing of both the generator and the motor (two-unit system) or the single unit where both functions are combined in one machine?

A. Carbon dust is an excellent conductor of electric current and, when spread over the surface of an insulator, it causes the latter to become conducting as well. Consequently, it is likely to short-circuit the commutator bars by lodging between them. It will cause leakage across fiber or other insulating bushing of brush holders when a sufficient deposit accumulates on them. It will penetrate the armature and field windings of the machine and may cause trouble by grounding or short-circuiting them. Especial care should be taken to remove all traces of carbon dust after sanding-in the brushes.

Q. How often should the commutator be inspected?

A. The commutator is the most vulnerable part of any direct-current machine, whether it be a generator or motor, and it should accordingly be inspected at more frequent intervals than any other single part of the entire system. The efficiency of both the generator and the motor depend upon it to a very great extent. Most of the failures of starting and lighting systems that are not due to poor condition of the battery may be traced directly to the commutator.

Q. What is the function of the brushes?

A. To conduct the voltage and current induced in the armature by its revolution through the lines of force created by the magnetic field, to the outer circuit, in the case of an electric generator; and to conduct the operating current to the armature windings from the battery, in the case of the starting motor.

Q. Why must the brushes bear evenly over their entire surface on the commutator?

A. Because their current-carrying capacity depends upon their size, and the latter is based upon the entire surface of the end of the brush making efficient contact. If the brush does not make uniform contact, those parts of it that do not touch the commutator will cause arcing or heavy sparking at the gap thus created, resulting in damage to both the commutator and the brush.

Q. Why are springs of different strengths used on generators and motors of different makes to hold the brushes against the commutator, though the machines are of practically the same capacity, operate at the same voltage, and are in other respects very much alike?

A. The carbon compounds of which the brushes are manufactured differ greatly in their conductivity and resistance offered to the passage of the current, and these differences call for greater or less spring pressure to hold the brush against the commutator surface in order to make efficient contact over the entire surface of the brush. Every maker has his own standard in this particular respect.

Q. Why is it not advisable to use brushes other than those supplied by the manufacturer as replacements on a machine?

A. For the reasons just given above. The manufacturer has adopted certain standards for the operation of his machines, and the brushes supplied have been made particularly to comply with those standards. No other brushes will do so well, and some will result in injury to the machine.

Q. When inspection shows that the brushes have worn down unevenly, what should be done?

A. They should be sanded-in with a strip of fine sandpaper, such as No. 00, preferably already worn if the brushes are very soft. (See instructions for doing this properly in connection with machines of different makes.) No more should be removed than is absolutely necessary to bring the end of the brush to a firm contact all over its bearing surface on the commutator; and the end of the brush, after the completion of the operation, should not show any deep scratches or pit marks. Unless the surface is smooth and true, injurious sparking will result, and the efficiency of the machine will be decreased.

Q. If, with a smooth and true surface, the brush still fails to make good contact, what is the trouble?

A. The brush has probably worn down until it is too short for the spring to exert sufficient force against it to hold it against the

commutator properly, or the spring itself may be at fault. Wear of the brush beyond the point where it is any longer of service will most often be the cause.

Q. Where the brushes are true and are making good contact against the commutator, but the machine is inoperative, all other parts of the system being in good condition, what is likely to be the trouble?

A. One of the pigtails, or short flexible connections, of the brushes may have shaken out from under its spring clip. This breaks the circuit, just as a parted wire or a ruptured connection at a terminal in any other part of the system would.

Q. How often is it necessary to replace the brushes?

A. This differs so much with different makes of machines that it cannot be answered definitely, even as an average. On two-unit systems, the generator brushes will naturally require replacements much sooner than those of the starting motor, as the starting motor is only in operation for very short periods, while the generator is working constantly. On single-unit types, this naturally does not apply, as, whether the armature has one or two sets, they are always in use. Ordinarily, brushes should not require replacement under a year, and frequent instances are known of their having lasted for two years or more. It depends upon the care given the commutator and brushes quite as much as upon the mileage covered, as, if allowed to run dirty for any length of time, the brushes will wear away much faster than if kept in good condition. The best rule for the replacement of the brushes on all makes of machines is to renew them as soon as they have worn to a point where the springs no longer hold them firm against the commutator. When they have reached this condition, the vibration and jolting of the car is likely to shake them out of contact, which results in sparking.

Q. What is the "third brush", and what is its function?

A. This is an extra brush used on a generator. Its purpose is to control the amount of current supplied by the armature to the shunt-field winding as the speed increases. In other words, it regulates the output of the machine and prevents it from being burned out when the speed of the engine becomes very high.

Q. Does it differ from the other brushes in construction or in the care required?

A. It is a carbon brush of the same nature as the others used on the same machine, and the care required to keep it in good condition does not differ. However, it is mounted in an independently adjustable holder so that it may be moved backward or forward with relation to the main brushes in order to increase or decrease the output of the generator. (See instructions [Delco] on this point.)

Q. Is it ever necessary to alter the location of the brushes of a machine?

A. Except on generators fitted with the third-brush method of regulation, on which it may be necessary to shift the main brushes slightly to avoid having the third brush come in contact with one of them when moved to change the output, it should never be necessary to shift the location of the brushes. Brush location has an important bearing on the operation of the machine, and, in designing it, the maker has fixed the location of the brushes to conform to its other characteristics. Many machines have no provision for adjusting the brushes in this respect, while some manufacturers caution the user particularly against altering their location.

Q. How much spring pressure is usually employed to hold the brushes of the generator and starting motor against the commutator?

A. This varies with different makes of machines and should be ascertained from the maker's instructions in every case in order to check up properly. In the various models of the Gray & Davis starting motors, this spring pressure ranges from $2\frac{1}{4}$ to $3\frac{1}{2}$ pounds, which is the minimum necessary. In other words, the brush must be held against the commutator with this amount of pressure in order to operate efficiently. While there will be a loss if the pressure drops below the minimum, there is no advantage in greatly exceeding it, as excess pressure simply causes greater friction loss without any compensating gain in power. Generator-brush pressures are much less than those employed on starting motors, owing to the smaller amount of current handled.

Q. How can the proper spring pressure of the brushes be checked?

A. With the aid of an ordinary spring scale of the direct-pull type, in which the pull on the hook draws the pointer down over the scale. A scale reading to five pounds is adequate for the purpose; one intended for heavy weights is not likely to be so accurate. Attach

the hook of the scale to the brush and pull until the brush is just clear of the commutator. The scale will then register the pull in pounds. Where there is nothing on the brush to which to attach the hook, such as a screw, place a thin piece of wood on the brush face before passing the hook of the scale around it, to prevent injuring the contact face of the brush. In this case, the spring pressure as shown on the scale will exceed the necessary minimum, as the spring must be compressed further than it would be when in operation, in order to operate the scale. This should be allowed for when taking the reading.

Q. When is it advisable to check the spring pressure of the brushes?

A. When there is undue sparking at the commutator, while the commutator and brushes are all in proper condition, i. e., clean, and bearing uniformly over their entire surface so that the sparking is not due to any fault in either of these essentials.

Q. When the brushes and commutator are in good condition and the spring=scale test shows that the brushes are being held against the commutator with the necessary amount of pressure, what is likely to be the cause of the sparking?

A. There may be a short-circuited or open coil in the armature.

STARTING MOTOR

Q. In what way does the starting motor of a two=unit system differ from the generator?

A. It is a simple series-wound machine having but one winding of coarse wire on the fields, and all the current from the battery passes through its armature coils and field windings.

Q. Is it subject to electrical faults other than those already referred to in connection with the generator?

A. No. The care and the nature of the tests required to locate faults are the same. The commutator should be kept clean, brushes bearing firmly on commutator, and all connections kept tight. The same instructions for sanding-in brushes and keeping the commutator in good condition apply as in the case of the generator.

Q. When the starting motor fails to operate, what is likely to be the cause?

A. In the majority of instances, a low state of charge or a

wholly discharged battery will be responsible. If the battery is all right, a loose connection at the battery, switch, or motor, or a short-circuit in some part of this wiring may be the cause. Should the battery be properly charged, all wiring and connections in good condition, switch contacts clean, etc., the starting gears may be binding, owing to dirt or lack of alignment between the motor shaft and the flywheel of the engine. In this case, the motor will attempt to start when the current is first turned on, but will be held fast. Loosen the holding bolts and line up the motor, cleaning the gear teeth if necessary.

Q What is likely to be the cause of the starting motor running slowly and with very little power?

A. Exhausted battery, poor switch contacts, loose connections, partial ground or short-circuit in wiring causing leakage, improperly meshing gears, dirty commutator, brushes making poor contact owing to weak springs or worn brushes, or a ground in the motor itself. The remedies for all these faults have been given already.

Q. When the battery and all connections and wiring are in good condition, but the motor fails to crank the engine, what is likely to be the cause?

A. The engine may be too stiff. If it has been overhauled just previously, the main bearings may have been set up too tight. Test with the starting crank to see if it can be turned over easily by hand. If unusual effort is required, easing off the bearings should remedy the trouble. Should the engine not turn over as soon as the switch is closed, release immediately, as otherwise the battery will be damaged.

Q. When the engine does not start within a few seconds, why is it better to use the starting motor intermittently than to run it continuously until the engine does fire?

A. The intermittent use of the starting motor, say ten seconds at a time, with a pause of half a minute or a minute between attempts is easier on the battery. If allowed to rest for a short period, the storage battery recuperates very rapidly. Consequently, the operation of the starting motor for two minutes, divided into twelve periods of ten seconds each, will not run the battery down to anything like the extent that its continuous operation for the same length of time would. Moreover, this intermittent method of operation increases the chances

of starting under adverse conditions, as, in very cold weather, every time the battery is allowed to rest, it will be able to spin the engine at its normal starting speed, whereas if the starting motor is operated continuously, the battery will become so weak that the engine will be turned over very slowly toward the end of the period in question.

Q. Why is it that a starting motor capable of turning an engine over at a speed anywhere from 75 to 150 r.p.m. will sometimes fail to start the engine, whereas hand cranking subsequently resorted to will succeed?

A. It must be borne in mind that the operation of starting an engine in cold weather involves several factors. (1) The pistons, crankpins and crankshaft (bearings) must be broken away, i.e., forcibly released from the hold that the gummed lubricating oil has on them, before they can be moved. The great difference between the power required to do this in summer and in winter is shown by the greatly increased amount of current used by the starting motor. (2) Gasoline and air must be drawn into the cylinders, to effect which in sufficient quantity to start the engine requires quite a number of revolutions. (3) The gasoline must be vaporized so that it will mix with the air, which involves more turning of the engine to create the necessary heat by compression in the combustion chambers and the friction of the moving parts. In the application of energy in any form, two factors are always involved, i.e., the unit, or quantity of power applied, and the length of time during which it is applied. The starting motor cranks the engine at a comparatively high speed for a brief period. In hand cranking, a smaller unit of power is employed, and the speed of cranking is accordingly less, but its application is continued for a much longer time. The failure of the starting motor is not due to its inferiority to hand cranking, but simply to the fact that the battery has become exhausted. Success in hand cranking where the starting motor has failed is usually due to the fact that the starting motor has done all the preliminary work, failing in the end simply because the storage battery did not have sufficient energy to finish the task. No electrical starting system can ever be any stronger than its storage battery, or source of energy.

Q. Why is it not necessary to protect the starting motor or its circuit by fuses or other protective devices as in the case of the generator?

A. A simple series-wound machine (practically all electric starting motors are of this type) is capable of standing exceedingly heavy overloads for short periods, it being nothing unusual for these small motors to have a factor of safety of five, or even seven, for a limited time, that is, they will take five to seven times the normal amount of current for a brief period without injury. As a matter of fact, the starting motor can utilize all the current the battery is capable of supplying, provided the motor is free to move. If the engine is stuck fast or some part of the starting system has gone wrong so that the electric motor cannot turn over, then there is danger that the motor may be damaged unless the switch is opened at once. This, together with the fact that the maximum load which may be placed on the motor at different times is such a variable quantity, would make it a difficult matter to provide a fuse that would not blow unnecessarily. The only object of the fuse would be to protect the motor windings, and, as the latter can stand all the current the battery can supply, the only source of danger is the possibility of the motor being held fast so that its armature cannot revolve.

WIRING SYSTEMS

Different Plans

Q. What is the difference between the single-wire and the two-wire systems?

A. In the single-wire there is but one connection to the operating circuit by means of a wire or cable, the circuit being completed in every instance by *grounding* the other side of the circuit. For this reason the single-wire is also referred to as a grounded system. In the two-wire system, copper wires or cables are employed to complete the circuits between the generator and battery and between the battery and the starting motor, as well as to the lamps.

Q. What forms the return circuit of a single-wire system?

A. The steel frame of the chassis.

Q. How are the various circuits grounded?

A. In the case of the battery, a special ground connection is usually made by drilling the frame and fastening a clamp to it. The ground cable from the battery is attached to this clamp. The generator and starting motor are grounded internally, i.e., the end of a winding or of a brush lead that would be taken out to form the

return side of a two-wire system is connected to the frame of the machine, and the latter completes the connection to the chassis through its holding bolts or other means of attachment. One side of all lamp sockets is usually grounded, so that the bulb itself completes the connection when fastened in place. Sometimes there is a special ground connection from the battery for the return side of the ignition or lighting circuits, and this ground wire is fused.

Q. What are the advantages and disadvantages of the single-wire system?

A. It greatly simplifies the wiring, as but one wire connection is necessary to the apparatus for each circuit, but this advantage renders it more susceptible to derangement through unintentional grounds or short-circuits, since the touching of any metal part of the chassis by a bare wire will cause a short-circuit. This depends to a very great extent, however, on the thoroughness with which the wiring is protected, and, with the armored cables or loom and the junction boxes used on modern installations, it is reduced to a point where both systems are practically on a par in this respect.

Q. What are the advantages and disadvantages of the two-wire system?

A. Each circuit is complete in itself thus rendering it easier to locate faults, while no one connection coming in contact with a metal part of the chassis will cause a ground. The wiring itself, however, is much more complicated, and, with the small space available on the bulb connections, it is more difficult to insulate them properly.

Q. Which system of wiring is favored?

A. The single-wire system will be found on the majority of cars, and the number of makers adopting it is steadily increasing.

Faults in Circuit

Q. What is the difference between a ground and a short-circuit?

A. So far as the effect produced is concerned, they are the same; the difference in the terms referring solely to the method of producing it. For example, if the cable of the starting motor circuit becomes abraded and the bare part touches the chassis or some

connecting part of metal, this is a *ground.* But it is also a short-circuit in that the circuit to the battery is completed through a shorter path than that intended. On the other hand, if, in a two-wire system, the two cables of the same circuit become chafed close together and their bared parts touch, this is a short-circuit, but it is not a ground. For all practical purposes, however, the two terms are really interchangeable when applied to faults in the circuit. (See Gray & Davis instructions.)

Q. How may grounds be located in a single-wire system?

A. In any of the fused circuits, the fuse will immediately blow out. Remove the fuse cartridge and shake it; if it rattles, the fuse wire has melted and the fuse is blown. If it does not rattle, short-circuit the fuse clips with the pliers or a piece of metal; a spark will indicate the completion of the circuit and will also indicate that the fuse has blown. If, on bridging the fuse clips, the lamp lights, or other apparatus on the circuit operates, the short-circuit was only temporary. This does not mean, however, that the fault has been remedied; the vibration of the car may have shaken whatever caused it out of contact and further vibration sooner or later will renew the contact with the same result. Inspect the wiring of that particular circuit and note whether the insulation is intact throughout its length. See that no frayed ends are making contact at any of the connections and that the latter are all tight and clean. In case the lamp does not light on bridging the fuse clips, see if the bulb has blown out; if not, use the test lamp by applying one point to the terminal and the other to various points along the wiring.

Q. Does the blowing of a fuse always indicate a fault in the wiring?

A. No. A bulb, in blowing out, frequently will cause a temporary short-circuit that will blow the fuse. To determine this, apply the points of the test-lamp outfit to the bulb contacts; if the test lamp lights, the bulb is short-circuited, and a new fuse and bulb may be inserted without further inspection of the circuit. In case the test lamp does not light on this test, it does not necessarily indicate a fault in the wiring of that circuit, though inspection is recommended before putting in new fuse and bulb. The blowing out of the bulb may cause a short-circuit, which is ruptured by the

current burning away the light metal parts that were in contact, such as a small piece of the filament.

Q. Can a short-circuit or ground occur without blowing a fuse?

A. Yes. No fuses are employed on starting-motor circuits owing to the very heavy current used and its great variation depending upon the conditions, such as extreme cold gumming the lubricating oil, tight bearings, binding of the pinion and gear, sprung shaft, starting motor out of alignment, or the like. On other circuits, the amount of current leaking through the fault in the circuit may not be sufficient to blow the fuse, as the capacity of the latter is such that it will carry the maximum current which the apparatus in that circuit will carry without damage—usually 5 or 10 amperes on lighting circuits and 10 amperes on generator-field circuits.

Q. How can such faults be noted?

A. The ammeter, or indicator, will show a discharge reading when the engine is idle and all lamps are switched off.

Q. What is the usual nature of such a fault?

A. The battery cut-out may have failed to open the circuit completely; a frayed end of the stranded wire at one of its connections may be making light contact which will permit a small amount of current to pass; a particle of foreign matter of high resistance may be bridging a gap either at the cut-out or some other part of the circuit; or the ignition switch may have been left on the *battery* contact so that current is flowing through the ignition coil.

Q. How may faults be located in a two-wire system?

A. With the aid of the test lamp, placing the points along the two wires of the circuit at fault from one set of terminal connections to the other, examine all connections in the circuit in question; note whether any wires have frayed ends and, if so, wind them tight together and dip in molten solder. See whether any moving part is in contact with one or both of the wires and whether the insulation of the latter has been worn off. In some two-wire systems there is a ground connection to the battery for the ignition system, in which case tests for grounds in the circuit in question must also be made. Examine the ignition switch for faults; also the switch of the circuit under test. This applies to single-wire as well as to two-wire systems.

Q. What is one of the most frequent causes of short-circuits in a two-wire system?

A. The bulbs and their sockets, owing to the very small amount of space available for the insulation. Dirt or particles of metal may be bridging the small gaps between their insulated contacts. A blown-out bulb also may be responsible, as previously mentioned.

Proper Conduction

Q. Why are different sizes of wire employed in the various circuits?

A. To permit the passage of the maximum current necessary in each circuit consistent with the minimum drop in voltage due to the resistance of the wire and its connections. The voltages employed are so low that any substantial drop due to this cause would seriously impair the efficiency of the system and particularly of the starting motor. For the latter the cables employed are not only large, but they are also made as short and direct as possible to save current as well as expense in the installation.

Q. What is the smallest wire that should be employed in automobile wiring?

A. No. 14 B. & S. gage, and this should be used only for the tail lamp, dash lamp, primary circuit of the ignition, or similar purpose. No. 10 or No. 12 is usually employed for the other lighting circuits.

Q. When, in making alterations on a car, it becomes necessary to extend a circuit, what should be done?

A. The ends of the wires should be scraped clean and bright for at least 2 inches, and a lineman's joint made with the aid of the pliers to insure having it tight. A lineman's joint is made by crossing the bared ends of the wires at their centers at right angles to each other, then wrapping or coiling each extending end tight around the opposite wire; the joint then should be soldered and well taped. A circuit should be extended only by using wire of the same size and character of insulation. None of the foregoing applies to the starting-motor circuit. It is inadvisable to lengthen this circuit if avoidable, but in the rare instances when it would be necessary, new cable of the same size or larger and with the same insulation should be cut to the proper length and the old cable

discarded. All terminals should be solidly fastened to the new cable by soldering.

Q. Why is it necessary to use such heavy cable for the connection of the starting motor to the battery?

A. It is essential that the exceedingly heavy starting current be transmitted with the minimum of loss.

Q. What is considered the minimum permissible loss in the starting-system wiring?

A. One maker specifies that the starting cable must be large enough to transmit a maximum current of 400 amperes with not over one-fourth volt total loss.

Q. Why is it important to hold the voltage drop down to a maximum so small as to be negligible in almost any other application?

A. Owing to the heavy current necessary, as a drop of but $\frac{1}{4}$ volt in potential with a current of 400 amperes represents a loss of 100 watts, or close to $\frac{1}{7}$ horsepower. Of course, the current seldom reaches such a high value as this except when a motor is exceptionally stiff, as in severe cold weather or just after its bearings have been set up very tight; moreover, this loss takes place at the instant of starting only, but it is just at this time that the highest efficiency and full battery power is needed to start without spinning the engine too much.

Q. On some of the early systems whose efficiency was not of the best, how can the proper size of cable to use between the starting motor and battery be determined?

A. Test the starting motor with a high-reading ammeter (scale should read to at least 300 amperes) after having made certain by hydrometer and voltage tests that the storage battery is fully charged. (See instructions regarding this.) Carefully note ammeter reading exactly at instant of closing switch, to determine maximum current flow. Measure the length of cable between the battery and the starting motor, i.e., both sides of starting switch. Then maximum starting current times 10.7 times number of feet of cable used, divided by .25 will give the cross-section of the wire in circular mills. For example, assume that the starting motor required a maximum of 300 amperes momentarily to break away the engine, and five feet of cable are employed for the connections. Then

$$\frac{300 \times 10.7 \times 5}{25} = 128{,}400 \text{ circular mills}$$

By referring to Table I, Part I, which gives the various size wires in circular mills and their equivalent in gage sizes, it will be noted that the closest approach to this is No. 00 cable, which is 133,079 circular mills, so that the largest size cable would have to be used. If the starting cable used on an old system which does not show particularly good efficiency is much smaller than this, it would probably be an advantage to replace it with larger cable, assuming, of course, that every other part of the system is in good condition and working properly.

Q. Why should connections be inspected frequently?

A. The vibration and jolting to which they are subjected in service is so severe that no mechanical joint can be depended upon to remain tight indefinitely.

Q. What harm does a loose or dirty connection occasion?

A. A loose connection causes the formation of an arc between its contacts whenever vibration causes the parts to separate temporarily. This wastes current and burns the metal away, leaving oxidized surfaces which are partially insulating, thus increasing the resistance at the connection. Dirt getting between the surfaces of the connector has the same effect; the resistance is increased and there is a correspondingly increased drop in the voltage of the circuit, which cuts down its efficiency.

Q. Why should all terminals be well taped when the battery, starting motor, generator, or other apparatus is temporarily disconnected for purposes of inspection or test?

A. To prevent accidental short-circuits which would be caused by these terminals coming in contact with any metal part of the chassis on a single-wire system. Such a short-circuit would ruin the battery and burn out any lamps that happened to be included in the circuit. This precaution applies with equal force to the two-wire systems, as in this case the terminals of the different wires might come together, or there might be a ground connection in the system.

PROTECTIVE AND OPERATIVE DEVICES

Q. What are the protective devices usually employed on electric systems?

A. Fuses in the separate lamp circuits, in the ground con-

nection, and in the field circuit of the generator on some machines; battery cut-out for the charging circuit; circuit-breaker which takes the place of the fuses.

Fuses

Q. What is a fuse and what is its function?

A. A fuse consists of a piece of wire of an alloy which melts at a low temperature and which will only carry a certain amount of current without melting, the latter depending upon the diameter of the wire, i.e., cross-section and the nature of the alloy. The fuse is usually in the form of a cartridge, the wire being encased in an insulating tube having brass ends, to which the ends of the wire are soldered. These brass ends are pressed into spring clips to put the fuse in circuit. In some cases open fuse blocks are employed, the wire itself simply being clamped under the screw connectors on the porcelain block. The function of the fuse is to protect the battery and the lamps when, by reason of a ground or short-circuit in the wiring, an excessive amount of current flows.

Q. When a fuse blows out what should be done?

A. Investigate the cause before replacing it with a new one. (See Wiring Systems.)

Q. Is it permissible to bridge the fuse gap with a piece of copper wire when no replacements are at hand?

A. Only in cases of emergency and after the short-circuit which has caused the fuse to blow has been remedied. The finest size of copper wire at hand, such as a single strand from a piece of lamp cord, should be used. If this burns out, there being no ground or short-circuit in the wiring, use two strands. Remove the wire as soon as a new fuse is obtainable.

Q. Why are fuses not employed in the starting-motor circuit?

A. In the starting circuit the current necessary is so heavy and varies so widely with the conditions that it would not be practicable to provide a protecting fuse.

Q. What does the intermittent blowing of the fuse on the same circuit indicate?

A. A short-circuit that is caused by the vibration, or jolting, of the car. The wire, lamp socket, or other part of the circuit that is at fault is shaken loose at times so that the circuit is operative, and a new

fuse may be inserted without instantly blowing, as it would do were the short-circuit constant. This is often the case as the car is stopped to inspect the wiring and insert the new fuse, and standing still lets the part drop out of contact; starting up shakes it into contact once more and blows the new fuse. Loose connections, wires with abraded insulation, and bulbs loosely inserted in their sockets are apt to cause trouble of this nature.

Q. Does the blowing out of a fuse necessarily indicate a fault in the wiring or in some other part of the system?

A. No, since a bulb in burning out will frequently cause the fuse to blow out. This is due to the fact that in breaking, the end of the parted filament of the bulb may fall across the other terminal where it comes through the glass, thus causing either a short-circuit or such a reduction in the ordinary resistance as to permit a much heavier rush of current than normal, with the result that the fuse goes. To test, leave burnt-out bulb in place temporarily; short-circuit fuse clips with screw driver or pliers, just touching them momentarily; if no spark results, replace bulb with a new one and test again; if a spark occurs, remove old bulb and test again with no lamp in place; then if no spark occurs in bridging the fuse terminals, the circuit is all right, and the fuse may be replaced.

Q. When all the lighting fuses blow out at once, what does this indicate?

A. A short-circuit across the lighting-switch terminals would cause this. In some switches with exposed rear terminals, it is possible to place a screwdriver or similar piece of metal in such a position that it bridges practically all the switch terminals. If the lighting switches were all closed at the time, this would short-circuit them.

Circuit=Breaker

Q. What is a circuit=breaker, and what is its function?

A. The circuit-breaker is an electromagnet with a pivoted armature and contacts, similar in principle to the battery cut-out. All the current used in the various circuits, except that of the starting motor, passes through it, and its contacts normally remain closed. The winding of the magnet coil is such that the normal current used by the lamps or ignition does not affect it, but the passage of an excessive amount of current will energize the magnet, attract

the armature, and break the circuit. The spring holding the armature away from the magnet will again close the circuit, and the circuit-breaker will vibrate until the cause has been removed. This is usually a ground or short-circuit. The function of the circuit-breaker is to protect the battery and lamps in place of the usual fuses.

Q. If the circuit=breaker operates when there are no faults in the wiring, what is likely to be the cause?

A. Its spring may have become weakened so that the vibration of the car causes it to operate on less current. The Delco circuit-breaker is designed to operate on 25 amperes or more, but, once started, a current of 3 to 5 amperes will keep it vibrating. If tests show that no faults in the wiring or connections exist, increase the spring tension with the ammeter in circuit until the reading of the latter indicates that the circuit-breaker is not operating on the current of less value than that intended. See that the contacts are clean and true.

Battery Cut=Out

Q. What is a battery cut=out?

A. It is an automatic double-acting switch which is closed by the voltage of the generator and opened by the current from the battery.

Q. Of what does it consist?

A. It is essentially a double-wound electromagnet with a pivoted armature and a pair of contacts. One winding, known as the *voltage coil,* is of fine wire and is permanently in circuit with the generator. The second winding of coarse wire is termed the *current coil* and is put in circuit by the contacts.

Q. Why is a cut=out necessary?

A. To protect the storage battery. When the generator speed falls below a certain point, it no longer produces sufficient voltage to charge the battery, and the latter then would discharge through the generator windings if not prevented. This discharge would always take place when the generator was idle, except for the cut-out.

Q. How does it operate?

A. When the generator voltage approaches the value necessary for charging, it energizes the magnet through the voltage

coil and closes the contacts, cutting in the current coil, which further excites the magnet and holds the contacts firmly together. The closing of these contacts puts the battery in circuit and it begins to charge. As soon as the generator speed falls below the point necessary for charging, the battery voltage overcomes that of the generator and sends a current in the reverse direction through the current coil, causing the contacts to separate and cutting the battery out of the charging circuit.

Q. If the generator is run for any length of time at or near this critical speed, what is to prevent the cut=out from vibrating constantly instead of working positively one way or the other?

A. The resistance of the windings is so proportioned that there is a difference of 1 to 2 volts between the cutting-in and the cutting-out points.

Q. What is the result when the battery cut=out—which is variously termed a cut=out, a circuit=breaker, an automatic switch, and a reverse=current relay or an automatic relay—fails to operate?

A. If it fails to cut in, i.e., the contacts do not come together, the battery does not charge and will quickly show a falling-off in capacity, such as inability to operate the starting motor properly or to light the lamps to full brilliance. If it fails to cut out, the battery charge will be wasted through the generator windings with the same indications of lack of capacity.

Q. What is the most frequent cause of trouble?

A. Automatic cut-outs have been perfected to a point where but little trouble occurs. Freezing or sticking together of the contacts due to excessive current will most often be found to be the cause of the device failing to cut out when the generator is stopped. The points should be cleaned and trued up as described in previous instructions. Loose or dirty connections making poor contact may insert sufficient extra resistance in the circuit to prevent the device from cutting in at the proper point. Excessive vibration, particularly when the cut-out is mounted on the dash, may prevent the contacts from staying together as they should when the engine is running at or above the proper speed. See that the cut-out is solidly mounted. Temporary loss of battery capacity may be due to slow driving over rough roads at about the speed at which the cut-out is designed to put the battery in circuit.

Q. None of the above causes existing, what further tests may be made?

A. The windings may be tested as already described for the generator windings, but trouble from this source is equally rare. If the contacts are clean and true and the connections are tight, look for a loose connection elsewhere, as at the generator or battery or the ground on the frame. A loose connection vibrates when the car is moving, constantly opening and closing the circuit and causing the cut-out to do likewise, so that the battery does not charge. A wire from which the insulation has been abraded will also vibrate, owing to the movement, causing an intermittent short-circuit. With all contacts and connections in good condition, failure to cut out indicates a ground or short-circuit between the battery and cut-out; failure to cut in indicates similar trouble between the generator and the cut-out.

Q. Is a battery cut-out necessary on every electrical system?

A. No. On single-unit systems of the type of the Dyneto, in which the generator becomes *motorized* as soon as its speed and consequently its voltage drops below a certain point, the battery is always in circuit. A plain knife-blade switch, which also controls the ignition, is closed to start and left closed as long as the car is running. But the engine must not be allowed to run at a speed below which it generates sufficient voltage to charge the battery, nor must the switch be left closed when the engine is not running; otherwise, the battery will discharge through the generator windings.

Q. After having trued up points of a battery cut-out, what precautions should be taken in adjusting them?

A. To insure proper operation, they must be set to the distances given in the manufacturer's instructions. This refers not only to the gap between the contact points themselves, but also to the distance that the armature must be set from its backstop when the points are open and to the air gap between the armature and the magnet. These distances are very small in every case, and it is important that they be adjusted accurately. They differ slightly on cut-outs of different makes and also on different models of the same make. For example, in the Gray & Davis cut-out, the distance between the contact points should be .015, the air gap between the armature and its backstop not less than .010, and the armature air gap, or distance between the armature and the magnet face, .030. These dimensions

refer to the flexible, or spring-arm type, while in the solid-arm type of the same make, they are .010 for the distance between the contact points and .015 for the armature air gap, it being necessary that the armature should be set parallel with the pole face of the magnet.

Q. How can these small distances be accurately determined with the facilities ordinarily found in a repair shop?

A. The manufacturers usually supply a small adjusting wrench, the different edges of which have been ground to varying thicknesses representing the proper distances for the various gaps. Lacking one of these, small pieces of strip brass or steel may be ground or filed down to the proper size and gauged with a micrometer, which should be part of the equipment of every garage. The strips should be stamped with the dimensions and name of gap for identification.

Q. How often will the point of a battery cut-out need adjustment, or truing up?

A. Service conditions vary so greatly that it is impossible to give any definite average for this, particularly as the instruments themselves also are a variable quantity, but, under ordinarily favorable conditions, they should not require attention more than once a year.

Contact Points

Q. Why is it necessary to make contact points of such an expensive metal as platinum, and why is the latter sometimes alloyed with irridium?

A. There is no other metal which withstands the oxidizing effect of the electric arc and still maintains a clean and bright conducting surface as does platinum. Irridium is added to make the platinum harder, so that it will be more durable. On cheaply made instruments in which no platinum has been used in the contacts, trouble will be experienced constantly with the contacts.

Q. Is there any substitute for platinum or any metal that approaches it in adaptability for contact points?

A. There is no substitute for platinum, and the only metal that approaches it is silver. Where contact points only separate occasionally at intervals, as in the Remy thermoelectric switch, the use of silver contacts is permissible; but in a battery cut-out, or a regulator in which the vibration of the points is more or less constant, nothing will serve so reliably as platinum.

Q. What is the cause of the platinum contacts burning into such irregular ragged forms?

A. When a current of electricity passes through a contact of this nature, the material of the positive electrode (i.e., contact point connected to the positive side of the circuit) is carried over by the current in the shape of metallic vapor, or infinitely fine particles, and deposited on the negative electrode. The positive consequently takes on the form of a sharp point, while the negative has a depression formed in it, usually referred to as a "peak and crater", which the two points resemble in miniature after long use. This peak and crater effect is much more noticeable in an old-style carbon arc lamp after it has been burning only a few hours.

Q. What can be done to prevent this?

A. The passing of the metal from one electrode to the other cannot be prevented, as it is a function of any arc or spark. It can be minimized, however, by keeping the contacts in good condition so that the sparking is reduced to a minimum.

Q. Can the formation of the pack and crater effect, which so greatly reduces the efficiency of the contacts, be avoided?

A. The use of a reversing switch in the circuit, as in the case of the magneto or the battery-type interrupter which changes the direction in which the current flows through the points every time it is turned on, will overcome this. Where there is no reversing switch in the ignition circuit or where one cannot be used, attention to the points at regular intervals will prevent this effect from reaching a stage where most of the point has to be filed away to true it up.

Q. In the use of the file, sandpaper, or emery cloth in this connection, just what is meant by truing the points up?

A. Their surfaces must be made exactly parallel to one another so that when the points come together they touch uniformly over their entire surfaces. In the hands of the unskilled user, there is a tendency to bear down sidewise with the file, thus forming rounded edges on the points. In addition to having the faces of the two points perfectly parallel, the face of each point must be at right angles to its sides. Otherwise, there is bound to be unnecessary sparking between the points, and this causes them to burn away again much sooner. It is scarcely necessary to add that as little as possible of the metal should be removed. As long as there is enough of the platinum left

to make true parallel surfaces, the points need not be replaced if the means for adjustment permits utilizing them when worn far down.

Q. What is the cause of the points freezing, or sticking, together?

A. Permitting them to wear down to a point where they are in very poor condition and where the gap between parts of their surfaces causes the formation of a heavy arc, or hot flash of current, which practically welds them together. By giving them the necessary attention at regular intervals, this may be avoided.

Q. How often should the contact points need attention?

A. When new, they should run for a year or more without any attention. After they have been trued up, the succeeding interval will often depend upon the skill and care with which this has been carried out.

Switches

Q. How do switches as employed on the automobile differ in principle and operation?

A. Starting-circuit switches are either of the knife-blade or the flat-contact type, while in the majority of cases the lighting switches are of the push-button type, though knife-blade switches are used for this purpose also. In some instances, one of the brushes of the machine is made to serve as a switch, as in the Delco. Ordinarily, the switch is normally held open by a spring and is closed by foot pressure, the spring returning it to the open position as soon as released. A variation of this is the Westinghouse electromagnetically operated switch in which a solenoid takes the place of foot operation. The circuit of the solenoid is controlled by a spring push button, which is normally held out of contact. Single-unit systems, such as the Dyneto, in which the machine automatically becomes motorized when the speed drops below a certain point, are controlled by a standard single-throw single-pole knife-blade switch which is left closed as long as the machine is running.

Q. What faults may be looked for in switches?

A. Loose connections; weakening of the spring; burning of the contact faces in the knife-blade type, due to arcing caused by releasing too slowly; dirt or other insulating substance accumulating on the contact faces of the flat-contact type; failure to release through binding.

Q. Why is it important to keep the switch contact faces clean and bright?

A. Dirt or burned surfaces increase the resistance and cause a drop in the voltage at the starting motor. The energy represented by an electric current is a measure of the volume or amperes times the voltage or pressure under which it flows, and, as such low voltages are used, only a slight falling off represents a serious percentage of the total potential. With a dirty switch or one that makes poor contact, current that should be utilized in the starting motor is wasted in overcoming the resistance of the switch.

Q. Why is it inadvisable to insert an extra switch in the starting circuit, as is done in some cases by owners to insure against theft?

A. Because of the drop in voltage. The loss in switches as designed for lighting circuits is about 1 per cent, or a little over 1 volt. If the same switch is used on the low voltage of the starter system, the loss is then equivalent to about 10 per cent.

LIGHTING AND INDICATORS

Lamps

Q. How many types of bulbs are there in general use on automobiles?

A. Four: miniature and candelabra screw base, and single- and double-contact bayonet-lock base, both of the latter being of the candelabra size.

Q. Are these types equally favored?

A. No. The screw-base type, particularly in the miniature size, will be found only on old cars, and this type, generally speaking, is practically obsolete on the automobile, as the vibration tends to unscrew the lamp. Of the bayonet-lock type, the single-contact style is steadily gaining favor. Ten million bulbs for automobile lighting were produced in 1915 (S.A.E. report) and of these 67 per cent were of the single-contact type.

Q. In how many different voltages are these bulbs made?

A. Four: a 6—8-volt bulb for a 3-cell or 6-volt system; 12—16-volt bulb for 6-cell or 12-volt systems; and 18—24-volt bulbs for 9-cell systems; 3—4-volt bulbs for tail-light and dash-light use, where these lights are burned in series on a 6-volt system.

Q. Are these the only voltages in which the bulbs are made?

A. No. They are the types that are being standardized to reduce the stock of replacements that it is necessary for a garage to carry. It has been customary for the lamp manufacturer to supply bulbs made exactly for any voltage that the maker of the electric system ordered. Taking into consideration only the standard sizes now listed for use on 3-, 6-, and 9-cell systems, and the different bases regularly used, there are about twenty-four different bulbs that should be stocked by a garage. In addition, about forty other sizes are in general use, and if individual voltages had to be supplied, considering the different standard bases, a stock of over two-hundred different bulb sizes would be required.

Q. Why is the voltage of a bulb expressed as "6—8", "12—16", etc.?

A. Owing to the rise and fall of the battery voltage according to its state of charge, this variation must be provided for, or the lamps would be burned out when the battery was fully charged. Headlight bulbs for 3-cell systems are made for $6\frac{1}{2}$ volts, while the side, rear, and speedometer lights are made for $6\frac{3}{4}$ volts, owing to the lesser voltage drop in their circuits, but they will all operate satisfactorily on a potential that does not exceed 8 volts or does not drop below 6 volts.

Q. When all the lamps burn dimly, what is the cause?

A. The battery is nearly exhausted, in which case its voltage will be only 5.2 to 5.5 volts for a 3-cell system. The car should be run with as few lights as necessary to permit the generator to charge the battery quickly.

Q. What is the cause of one light failing?

A. Bulb burned out or its fuse blown; examine the fuse before replacing the bulb and if blown, examine the wiring before putting in a new bulb. Poor contact; see that the lamp is put in properly and turned to lock it in place. A double-contact bulb may have been put in single-contact socket, or *vice versa.*

Q. Why will one lamp burn much brighter than the other?

A. A replacement may have been made with a bulb of higher voltage; a 12-volt bulb will give only a dull red glow on a 3-cell system. Where the difference is not so marked as this, but still very perceptible, it may be due to the difference in the age of the

lamps. As a bulb grows old in service, its filament resistance increases, so that it does not take so much current and will not burn as brightly as when new.

Q. Will the failure of a bulb cause its fuse to blow though there is no fault in its circuit?

A. This sometimes happens owing to the breaking down of the filament, causing a short-circuit when the lamp fails.

Q. Can the proper voltage bulbs needed for any system always be told simply by taking the total voltage of the battery, i.e., the number of cells times 2?

A. No. Always examine the burned out bulb and replace with one of the same kind. Many 6-cell systems use 6-volt lamps and are known as 12—6-volt systems. The battery is divided into two groups in series parallel for lighting and sometimes for charging, all the cells being in series for starting. Other arbitrary voltages are also adopted; for example, 14-volt bulbs are used on 12-cell systems, the battery being divided in the same manner, so that this would be a 24—12-volt system. The only safe way to order replacements is to give the voltage on the printed label on the old bulb and state the make of the system on which it is to be used.

Q. What type of bulb is used where the current is taken from the magneto, as on the Ford?

A. As supplied by the maker, only the headlights are wired, and they are in series, and in recent models a 9-volt bulb is used, but the above instructions for replacements will apply here also. Ordinarily, double-contact bulbs are required, unless the fixtures are insulated from one another, in which case the single-contact type can be used.

Q. Why is a bulb of a voltage lower than that of the system itself often employed on 6-, 9-, and 12-cell systems?

A. The lower the voltage, the thicker the filament can be made. A short comparatively thick filament concentrates the light and makes the bulb easier to focus; it is also much more durable than the thin filament required for higher voltages.

Q. Under what conditions will the best results be obtained from the head lamps?

A. When the bulbs are in proper focus with the lamp reflectors. The usual focal length for headlight bulbs is $\frac{13}{16}$ inch, and the

focal length of the reflector is made greater than this to permit of adjustment. The center of the filament should be back of the focus of the reflector to spread the beam of light. In this position a greater number of the light rays are utilized and redirected by the reflector, producing a higher beam candlepower. If the center of the filament is forward of the focus, the lower part of the reflector will produce the most glare and throw it into the eyes of pedestrians and approaching drivers.

Q. How can the headlights be focused?

A. Place the car in position where light can be directed against a wall about 100 feet distant. Adjust the bulbs backward or forward until the spotlight on the wall is most brilliant and free from black rings and streaks. When this position is found, lock the bulb securely in place. Focus each headlight separately. See that the lamp brackets are set so that the light is being projected directly ahead.

Q. How can metal headlight reflectors be cleaned when discolored?

A. Wash by directing a gentle stream of cold water against the surfaces and allow to dry without touching them. The reflectors should never be rubbed with cloth or paper as it will scratch the highly polished surfaces. If they become very dull, it will be necessary to have them replated.

Q. What is the meaning of the identification marks usually placed on bulbs, in addition to the voltage, such as "G-6"?

A. This refers to the size and shape of the bulb. The diameter of the glass bulb is expressed in eighths of an inch and its shape by a prefixed *G* for round (globular), *T* for tubular, *S* for straight-side, etc. Thus, G-6 is a round bulb $\frac{6}{8}$ inch or $\frac{3}{4}$ inch in diameter.

Instruments

Q. What instruments ordinarily are employed in connection with electric systems on the automobile?

A. Either a double-reading ammeter, a volt-ammeter, or an indicator, the first named being employed generally. The ammeter shows whether the battery is charging or discharging or whether no current is passing; the indicator reads either *Off* or *On*; while the voltammeter gives the voltage, usually upon pressing a button to put it into operation, in addition to the readings already mentioned.

Q. On what circuits are the indicating instruments placed?

A. The charging circuit from the generator to the battery, and the lamp and ignition circuits.

Q. Why is an ammeter not used for the starting=motor circuit?

A. The current is so heavy and varies so greatly with the conditions that an ammeter designed to give an accurate reading of it would not be sensitive enough to indicate the smaller amounts of current used by the lamps, or produced by the generator for charging. Furthermore, the starting motor is intended only to be used for very short periods, while the other circuits are in constant use.

Q. Do the small ammeters employed fail very often?

A. Considering the unusually severe treatment to which they are subjected by the vibration and jolting of the car, their failure is comparatively rare, but as the conditions are so severe for a sensitive indicating instrument, too much dependence should not be placed on the ammeter reading when making tests.

Q. What are the usual causes of failure?

A. Failure to indicate—the generator, wiring, and other parts of the circuit being in good operative condition—may be caused by the pointer becoming bent, so as to bind it; the pointer may have been shaken off its base altogether by the jolting, or one of its connections may have sprung loose from the same cause.

Q. How can the ammeter reading be checked?

A. By inserting the portable testing voltammeter in circuit with it, using the 30-ampere shunt and comparing the readings. The dash ammeter must not be expected to give as accurate a reading as the finer portable instrument. Failing the latter, a spare dash ammeter may be employed in the same manner and the spare may be tested beforehand by connecting to a battery of 4 dry cells in series; if brand new, they should give a reading of 18 to 20 amperes. Do not keep the ammeter in circuit any longer than necessary to obtain the reading, as it only runs the cells down needlessly.

Q. Should an ammeter ever be used in testing the storage battery?

A. No. Because it practically would short-circuit the battery, burn out the instrument, and damage the battery itself. Nothing but a voltmeter should be employed for this purpose, as its high

resistance coil permits only a small amount of current to pass. An ammeter reading from a storage battery gives no indication whatever of its condition, whereas the voltage affords a close check on the state of charge, varying from 1.75 for a completely discharged cell to 2.55 volts for a fully charged one, the readings always being taken when the battery is either charging or discharging. The voltage on discharge will not be as high as on charge, the conditions otherwise being the same.

Q. Why are indicators employed on some systems instead of ammeters?

A. As the indicator is not designed to give a quantitative reading, it need not be so sensitive as an ammeter and accordingly can be made more durable.

Q. What are the most frequent causes of failure of an indicator?

A. Usually of a mechanical nature caused by the jolting, such as the target being shaken off its bearings, broken wire, etc.

Q. When the engine is running slowly, and the ammeter or the indicator flutters constantly, going from "On" to "Off" at short intervals, in the case of the indicator, or from a small charging current to zero, in the case of the ammeter, what does this signify?

A. That the setting of the battery cut-out is very sensitive and that the engine is then running at or about the speed that the instrument should cut-in. Since the speed of an engine varies considerably when running slowly, picking up momentarily and then falling off for a longer period, there is a corresponding variation in the potential, causing the cut-out to operate intermittently. This is a condition that seldom occurs and results in no harm when it does.

Q. When the ammeter or indicator flutters in the same manner with the engine running at medium or at high speed, what does it indicate?

A. That there is a loose connection between the generator and the cut-out, or an intermittent short-circuit or ground caused by a chafed wire alternately making contact with some metal part owing to the vibration. It is much more likely to be simply a loose connection and will be found most often on the back of the cut-out itself. This should be remedied at once. If neglected, it will cause abnormal wear of the platinum points in the cut-out.

Q. When the ammeter does not indicate "Charge" though the engine is speeded up, but does register a discharge when the lights are turned on and the engine is idle, what is the nature of the trouble?

A. Either the generator is not producing current or the regulator (where an external type is employed) is not working properly. The generator brushes may not be making proper contact with the commutator, or there may be a loose, corroded, or broken connection in the generator cut-out battery circuit. Where a belt drives the generator, it may be too loose to run the machine at its proper speed.

Q. When the ammeter gives no charging indication though the lamps are off and the engine is speeded up, and gives no discharging indication though the engine is idle and lamps are switched on, what is likely to be the cause?

A. There is an open or a loose connection in the battery circuit or in the battery itself. The ammeter may be at fault. See that its indicating pointer has not become jammed nor dropped off its bearings.

Q. In case the ammeter indicates "Discharge" though the engine be idle and all lights turned off, what is the trouble?

A. There is a short-circuit or a ground somewhere in the lighting circuits or between the battery and the ammeter, as the discharge reading in such circumstances indicates a leakage of current; or the cut-out has failed to operate and still has the battery in circuit with the generator, though the engine is stopped. The ammeter pointer may be bent.

Q. When the meter indicates a charge though the engine is at rest, what is the nature of the fault?

A. The ammeter pointer has become bent or deranged so that it is stuck fast in place, showing a charge.

Q. When the ammeter charge indications are below normal, what is apt to be the cause?

A. The generator commutator or brushes may need attention, such as cleaning or sanding-in, or new brushes may be necessary. The generator speed may be too low; in case of belt drive, it may not be getting the benefit of the full speed of the engine owing to a slipping belt. The regulator (external type) may not be functioning properly, or there may be an excessive lamp load on the generator.

Q. When the ammeter charge reading is above normal, what is likely to be the cause?

A. There may be a short-circuited cell in the battery, or a short in the charging circuit, or the regulator (external type) may not be working properly.

Q. What will cause the discharge reading of the ammeter to become abnormally high?

A. The lamp load may be excessive, as where higher candle-power bulbs are used, or more lights than originally intended are put in the circuit. There may be leakage in some part of the lighting circuit, or the regulator contacts may be stuck together, permitting a discharge through it or through the generator.

ELECTRIC GEAR-SHIFT

Q. What is the operating principle upon which the electric gear-shifting mechanism is based?

A. That of the solenoid and its attraction for its core when a current is passed through its winding.

Q. What is the source of current supply for the electric gear-shift?

A. The storage battery of the lighting system. The operation of gear-shifting is carried out so quickly that only a nominal additional demand is made on the battery.

Q. How is the electric gear-shift controlled?

A. By a series of buttons corresponding to the various speeds and located on the steering wheel, and by a master switch.

Q. What is the object of the buttons, and what are they termed?

A. To partly close the circuit to the particular solenoid of the speed desired. They are termed "selector switches" since they permit selecting in advance the speed desired.

Q. Why is a master switch employed, and why is it so called?

A. To avoid the complication which would otherwise result from the necessity of providing two switches for each change of speed, i.e., a selector switch and an operating switch. It is termed a master switch because it controls the current supply to all of the circuits.

Q. Why is a neutral button provided in addition to the buttons for the various speeds on the selector switch?

A. To return any of the selector buttons to neutral without the necessity of going through that speed in case it is not desired to engage the speed in question after the button has been pushed. Also

to open any of the selector switches that may be closed when it is desired to stop.

Q. What is the neutralizing device?

A. It is a mechanism incorporated with the shifting mechanism to open the master switch automatically after the gears have been engaged.

Q. Why is the neutralizing device necessary?

A. If it were not provided, the master switch would remain closed, causing a constant drain on the battery and rendering the mechanism inoperative after one shift had been made.

Q. How many solenoids are provided in the standard three-speed and reverse gear box?

A. One for every movement necessary.

Q. Is the current sent through a solenoid in one direction to pull the shifting bar into it and then in the opposite direction to move the bar the other way?

A. No, the current is not reversed through the same solenoid. After the left-hand solenoid, operating the first-speed gear, for example, has pulled the shifter bar to the left, a second solenoid, on the opposite end of the same bar, is energized to pull it back to the right, to shift to second or intermediate. The current is sent through a different solenoid by means of the selector switches for each shift desired.

Q. When the electric gear-shift failed to operate, where would be the most likely place to look for the cause of the trouble?

A. First see that the battery is not exhausted, then that no connections between the battery and the terminal block have parted, thus cutting off the current supply. The wiring is so simple and so strongly protected that it is very unlikely to have anything happen to it except at the connections. This is likewise true of the solenoids.

Q. In case the battery is amply charged and nothing is wrong with the connections, what procedure should be followed?

A. Use the lamp-testing set described in connection with the lighting and starting systems and test out the various circuits as shown on the wiring diagram. In using this test, it must always be borne in mind that touching the two points to the same or connecting pieces of wire or metal will always cause the lamp to light. It is useful in this way for indicating the continuity of a wire, i.e., that it has not

broken under the insulation, but, until experience has been gained in its use, it will be nothing unusual to find that the points have been touched to connecting pieces of metal which have no relation to the circuit. As such metal will complete the circuit through the lamp, the latter will light, but without indicating anything of value to the trouble hunter. Always test the lamp itself before proceeding. It may have become partly unscrewed in its socket or its filament may have been broken.

BATTERY

Electrolyte

Q. Why is it necessary to refill the battery jars at regular intervals?

A. Because the heat generated in the cells evaporates the water from the electrolyte, and, if the latter is permitted to fall below the tops of the plates, they will dry out where they are exposed, and the heat of charging will then cause them to disintegrate, ruining the battery.

Q. Why should this be done at intervals of not less than two weeks?

A. Because the limited amount of electrolyte permitted by the restricted size of the cells over the plates—usually one-half inch—will be evaporated in that period by a battery that is in more or less constant use.

Q. Why should water alone and never acid or electrolyte be used to make up this loss?

A. Only the water evaporates, so that if either acid or fresh electrolyte is added, it will disturb the specific gravity of the solution in the cells and totally alter their condition.

Q. What is the reason that battery manufacturers insist that only distilled water or its nearest equivalent, rain water or melted artificial ice, be used for this purpose?

A. Because ordinary water contains impurities that are apt to harm the plates, such as iron salts, or alkaline salts that will affect both the plates and the electrolyte.

Q. What should be done to a battery that has had its efficiency impaired by being filled with impure water?

A. The cells should be taken apart, the separators discarded, the plates thoroughly washed for hours in clean running water

without exposing them to the air where they would dry, the jars washed out, the plates reassembled with new separators, the jars filled with fresh electrolyte of the proper specific gravity, and the battery put on a long slow charge from an outside charging source, i.e., not on the car itself. Unless there are proper facilities for carrying this out, it will be preferable to ship the battery back to the maker so that it can be given proper treatment, particularly as it is necessary to reseal the cells.

Q. How is electrolyte prepared?

A. By adding pure sulphuric acid a very little at a time to distilled water until the proper specific gravity is reached, and then permitting the solution to cool before using. The mixture must always be made in a porcelain, hard rubber, or glass jar; never in a metal vessel. Commercial sulphuric acid or vitriol should not be employed, as it is far from pure. Never add acid to water. When the two are brought together, their chemical combination evolves a great amount of heat, and the acid will be violently spattered about.

Q. How often should distilled or rain water be added to the cells?

A. This will vary not alone with different systems but with different cars equipped with the same system, owing to the difference in conditions of operation. The only way to determine this definitely is to inspect the cells at short intervals and note how long they will operate before the electrolyte gets close enough to the tops of the plates to require additional water. This may be a week, ten days or two weeks, or even more, if the car is not run much.

Q. When a battery requires the addition of water at very short intervals to keep the level of the electrolyte one-half inch above the plates, what does this indicate?

A. It shows that the battery is being constantly overcharged, which keeps it at a high temperature, causing excessive evaporation. This will usually occur where a car is in constant use during the day but is driven very little at night. It may be remedied by adjustment of the regulation so as to reduce the output of the generator. Where this is not possible, as in the case of simple bucking-coil regulation which is entirely self-contained and permits no variation, additional resistance may be introduced in the generator-battery circuit. This

may take the form of a small-resistance unit consisting of German silver or other high-resistance wire wound on a porcelain tube and mounted on the forward side of the dash. A single-pole knife-blade switch should be placed in the circuit with the resistance so that the latter can be cut in or out of the generator circuit as circumstances may require.

Q. How can the amount of resistance to be inserted in the circuit be figured?

A. By the use of Ohm's law. In this case, it would be $\frac{R}{E}=C$ or resistance divided by voltage equals current. How much resistance to use can only be answered by the conditions of operation. Where a car is used steadily during the day and very seldom at night, it may be necessary to reduce the charge by two-thirds. In the case of a 6-volt system normally charging at 12 amperes, this would require approximately 28 ohms additional, since $\frac{20}{7}=4$ amperes. This is on the assumption that the battery actually receives 12 amperes through the resistance of its original circuit. Seven is used as the voltage, since the generator of a 6-volt system generates current at 7 to $7\frac{1}{2}$ volts in order to overcome the voltage of the battery when fully charged. The amount of resistance wire necessary to give this resistance or any other resistance necessary may be found in tables of wire sizes and resistances of special wire employed for this purpose. The wire is bare and must be wound on the tube so that adjacent coils do not touch. An extreme instance is cited here. It may be necessary in many cases to reduce the charging rate by a very much smaller fraction. Unless trouble of the nature mentioned is experienced, the charging rate should not be altered.

Q. When the battery is constantly gassing, or "boiling", as the car owner usually puts it, what is the trouble?

A. It is being constantly overcharged. This will greatly reduce the life of the battery, and the charging rate should be reduced, as mentioned in the preceding answer. It is essential that the battery be kept fully charged; but if it is continually overcharged, this will keep the cells at an abnormal temperature which is injurious to the plates. The treatment to be given the battery will vary with the season, for the demand upon it is much heavier during cold weather than in summer.

Hydrometer Tests

Q. Why should the battery be tested with the hydrometer at regular intervals of a week or so?

A. Because the specific gravity of the electrolyte is the most certain indication of the battery's condition.

Q. What should the hydrometer read when the battery is fully charged?

A. 1.280 to 1.300.

Q. What point is it dangerous to permit the specific gravity of the electrolyte to fall below, and why?

A. 1.250; because below this point, the acid begins to attack the plates and the battery plates sulphate. The lower the specific gravity, the faster sulphating takes place.

Q. What should be done when the hydrometer reading is 1.250 or lower?

A. The battery should be put on charge immediately, either by running the engine or by charging from an outside source of current until the gravity reading becomes normal.

Q. If the hydrometer reading of one cell is lower than that of the others, what should be done?

A. Inspect the cell to see if the jar is leaking; note whether electrolyte is over the plates to the depth of ½ inch and whether the electrolyte is dirty. If these causes are not apparent, the cell will have to be opened and inspected for short-circuits from an accumulation of sediment in the bottom of the jar or from buckling of the plates.

Q. Are hydrometer tests alone conclusive?

A. No. To be strictly accurate, they should be checked by voltage tests, in addition.

Q. How should these voltage readings be taken?

A. With the aid of a portable voltmeter, using the low-reading scale, i.e., 0-3 volts, and always with the battery discharging, the load not exceeding its normal low discharge rate.

Q. Why should the test not be made with the starting-motor load?

A. Because the discharge rate while the starting motor is being used is so heavy that even in a fully charged battery in good condition it will cause the voltage to drop rapidly.

Q. Why should the voltage readings not be taken while the battery is charging?

A. Because the voltage of the charging current (always in excess of six volts) will cause the voltage of a battery in good condition to rise to normal or above the moment it is placed on charge, such readings are not a good indication of the battery's condition.

Q. What should the voltage of the cells be?

A. In any battery in good condition, the voltage of each cell at the battery's normal low discharge rate (5 to 10 amperes, as in carrying the lamp load) will remain between 2.1 and 1.9 volts until it begins to approach the discharged condition. A voltage of less than 1.9 volts per cell indicates either that the battery is nearly discharged or that it is in bad condition. The same state is also indicated when the voltage drops rapidly after the load has been on a few minutes.

Joint Hydrometer-Voltmeter Test

Q. What should the hydrometer and voltmeter readings be for a fully charged battery in good condition?

A. Hydrometer 1.275 to 1.300; voltage 2 to 2.2 volts per cell.

Q. What does a hydrometer reading of 1.200 or less with a voltage of 1.9 volts or less per cell indicate?

A. This shows that excess acid has been added to the electrolyte. Under these conditions, the lights will burn dimly even though the hydrometer test alone would appear to show that the battery is more than half charged.

Q. What does a hydrometer reading in excess of 1.300 indicate?

A. It indicates that an excessive amount of acid has been added to the electrolyte, regardless of whether the voltage reading is high, low, or normal.

Q. Where a low voltage reading is found, how can it be determined whether the battery is in bad condition or merely discharged?

A. Stop the discharge by switching off the load (lamps) and put the battery on charge, cranking the engine by hand. After a few minutes of charging, note whether the voltage of each cell promptly rises to 2 volts or more. Any cells that do not are probably short-circuited or otherwise in bad condition.

Q. How can a rough test of the condition of the battery be made without the use of any instruments?

A. On systems fitted with a battery cut-out in the generator battery circuit, remove the cover of the cut-out (the generator being stationary) and momentarily close the cut-out points with the finger. The discharge shown by the ammeter the monent the points are closed should be anywhere from 10 to 20 amperes, differing, of course, with different systems. In any case, it should be equal to or greater than the maximum normal output of the generator, provided the battery is at least three-quarters charged.

Q. What effect will allowing the electrolyte to fall too low in the cells have, apart from the damage that it will cause to the plates?

A. It will tend to increase the voltage if the battery is otherwise in good condition, and this may be carried to a point where it will burn out the lamps.

Q. What is meant by "floating the battery on the line"?

A. This describes the relation of the battery to the generator and lighting circuits in systems where the current for lighting is taken directly from the generator when running, any excess over the requirements of the lamps being absorbed by the battery. The moment the generator speed falls below the point where it supplies sufficient current to supply all that is needed for the lamps, the battery automatically supplies the balance. When the generator is idle, the battery, of course, supplies the current for lighting as well as for starting.

Gassing

Q. Why should the cell tops be wiped dry from time to time and the latter as well as the terminals be washed with a weak solution of ammonia and water?

A. As the charge approaches completion, the cells gas; when overcharged they gas very freely. This gas carries with it in the form of a fine spray some of the electrolyte, and the acid of the latter will attack the terminals and corrode them. Wiping clean does not remove this acid entirely, so the ammonia solution is necessary to counteract its effect, the ammonia being strongly alkaline.

Q. Why should an unprotected light, i.e., any flame or spark, not be allowed close to a storage battery?

A. Because the gas emitted by the battery on charge is hydrogen, which is not only highly inflammable but, when mixed in certain proportions with air, forms a powerful explosive mixture.

Q. What is the cause of gassing?

A. When a battery is charged, the water of the electrolyte is decomposed by the current into gases. During the early part of the charge these gases unite with the active material of the plates, but as the charge proceeds, more gas is evolved than the plates can take care of and it bubbles up through the electrolyte. This is known as the gassing point, and the temperature of the cell also begins to rise at that point.

Q. Is gassing harmful to the battery?

A. The greatest wear on the positive plates takes place during the gassing period, and, if carried too far, they may be injured by reaching a dangerous temperature (105° F., or over) which will tend to loosen the active material.

Q. How can gassing be checked?

A. By cutting down the charge. In some systems this can be effected by the insertion of extra resistance provided for the purpose. Where this cannot be done and it is necessary to keep the car running, turn on all the lamps or start the engine once or twice to reduce the charge of the battery. As the lamps usually consume 80 to 95 per cent of the generator output, they should be sufficient to prevent a further overcharge.

Q. Can the generator be disconnected from the battery to prevent overcharge?

A. Not unless it is short-circuited, as directed in the instructions covering different systems. Otherwise, it will blow its field fuse or, where one is not provided, burn out its windings, except in cases where special provision is made to guard against this.

Sulphating

Q. Why must a battery never be allowed to stand in a fully discharged state?

A. Because the acid of the electrolyte then attacks the plates and converts the lead into white lead sulphate which is deposited on them in the form of a hard coating that is impenetrable to the electrolyte, so that the plates are no longer active. The battery then is said to be *sulphated*.

Q. Can a sulphated battery be put in good condition, and what treatment must be given it to do so?

A. If the sulphating has not gone too far, the battery may be brought back to approximately normal condition by a long heavy charge at a higher voltage than ordinary. Where the battery has become badly sulphated, it is preferable to remove it from the car and charge from an outside source of current, as it may require several days to complete the process. (Note instructions regarding the running of the generator when disconnected from the battery, as otherwise it may be damaged.) If avoidable, the car should not run with the battery removed. If the battery has not stood discharged for any length of time, the charge may be given on the car by running steadily for 8 to 10 hours with all lights off. No lamps must be turned on, as the increased voltage is liable to burn them out.

Voltage Tests

Q. What is the purpose of the voltmeter in connection with the battery?

A. It is chiefly useful for showing whether a cell is short-circuited or is otherwise in bad condition.

Q. Can the voltmeter alone be relied upon to show the condition of the cells?

A. No; like the hydrometer, its indications are not always conclusive, and it must be used in conjunction with the hydrometer to insure accuracy.

Q. What type of voltmeter should be employed for making these tests?

A. For garage use, a reliable portable instrument with several connections giving a variable range of readings should be employed. For example, on the 0-3 volt scale, only one cell should ever be tested; attempting to test any more than this is apt to burn out the 3-volt coil in the meter. The total voltage of the number of cells tested should never exceed the reading of the particular scale being used at the time, as otherwise the instrument will be ruined.

Q. Must these readings be particularly accurate?

A. Since a variation as low as .1 volt (one-tenth of a volt) makes considerable difference in what the reading indicates as to the condition of the battery, it will be apparent that the readings must not only be taken accurately, but that a cheap and inaccurate voltmeter is likely to be misleading rather than helpful.

Q. What precautions should be taken before using the voltmeter?

A. Always see that the place on the battery connector selected for the contact is bright and clean and that the contact itself is firm, otherwise the reading will be misleading since the increased resistance of a poor contact will cut down the voltage.

Q. How is the instrument connected to the battery?

A. The positive terminal of the voltmeter must be brought in contact with the positive terminal of the battery and the negative terminal of the voltmeter in contact with the negative terminal of the battery.

Q. In case the markings on the battery are indistinct, how can the polarity be determined?

A. Connect the voltmeter across any one cell. Should the pointer not give any voltage reading, butting against the stop at the left instead, the connections are wrong and should be reversed; if the instrument shows a reading for one cell, the positive terminal of the voltmeter is in contact with the positive terminal of the battery. This test can be made without any risk of short-circuiting the cell, since the voltmeter is wound to a high resistance and will pass very little current. Such is not the case with the meter, which should never be used for this purpose.

Q. When the battery is standing idle, what is the cell voltage and why is this not a good test?

A. Approximately two volts, regardless of whether the battery is fully charged or not. Voltage readings taken when the battery is on open circuit, i.e., neither charging nor discharging, are only of value when the cell is out of order.

Q. If the battery is in good condition and has sufficient charge, what should the voltmeter reading show?

A. Using the lamps for a load, the voltage reading after the load has been on for five minutes or longer should be but slightly lower (about .1 volt) than if the battery were on open circuit.

Q. When one or more cells are discharged, what will the reading show?

A. The voltage of these cells will drop rapidly when the load is first put on and sometimes even show reverse readings, as when a cell is out of order.

Q. What will the voltmeter indicate when the battery is nearly discharged?

A. The voltage of each cell will be considerably lower than if on open circuit after the load has been on for five minutes or more.

Q. How can the difference be distinguished between cells that are merely discharged and those that are in bad condition?

A. Put the battery on charge, cranking the engine by hand to start, and test again with the voltmeter; if the voltage does not rise to approximately 2 volts per cell within a short time, it is evidence that there is internal trouble which can be remedied only by dismantling the cell.

Q. What effect has the temperature on voltage readings?

A. The voltage of a cold battery rises slightly above normal on charge and falls below normal on discharge. This last is one of the chief reasons for its decreased efficiency in cold weather.

Q. What is the normal temperature of the battery and to what does this refer?

A. The normal temperature of a battery is considered at 70° F., but this refers to the temperature of the electrolyte in the battery as shown by a battery thermometer and not to the temperature of the surrounding air. If the battery has been charging at a high rate for some time, it may be normal even though the weather be close to zero at the time.

Sediment

Q. What is the cause of sediment or mud accumulating in the jars, and why must it be removed before it reaches the bottoms of the plates?

A. This sediment consists of the active material of the plates, which has been shaken out, due to the loosening caused by the charging and discharging, and aggravated by the constant vibration. It must never be allowed to reach the plates, as it is a conductor and will short-circuit them and thus ruin the battery.

Q. How long will a battery stay in service before this occurs?

A. This depends on the type of jar employed and the treatment that the battery has received. If it has been kept constantly overcharged, or if discharged to exhaustion in a very short period, as by abuse of the starting motor when the engine is not in good

starting condition, or if it has been subjected to short-circuits by grounding or by dropping tools on its terminals, the plates will disintegrate much quicker than where proper treatment has been given it. With the old-style jar, only an inch or so is allowed to hold this accumulation of sediment below the plates, while in later types fully 3 inches or more are allowed in the depth of the cell for this purpose. A battery with jars of the latter type that has been cared for properly should not require washing out under two years. The procedure is the same as that given for removing the effects of impure water. The plates must never be allowed to dry.

Washing the Battery

Q. What is meant by washing the battery, and why is it necessary?

A. Washing a battery involves cutting the cells apart, washing the elements and the jars, and reassembling with new separators and new electrolyte. It is necessary to prevent the accumulation of sediment, consisting of active material shaken from the plates, to a point where it will touch them and thus cause a short-circuit.

Q. How often is it necessary to wash a battery?

A. This will depend on the type of cell in the battery and the age of the latter. If the battery has the modern-style jar with extra deep mud space, it probably will not be necessary to wash it until it has seen two to three seasons' use. With the older form of cell in which the space allowed for sediment is much less, washing doubtless will be necessary at least once a season. As the battery ages, it will be necessary to wash it oftener.

Q. What other causes besides the type of jar and the age of the battery influence the frequency with which it is necessary to wash the battery?

A. The treatment the battery has received. If it has been abused by overcharging and permitting the cells to get too hot, the active material will be forced out of the grids much sooner.

Q. How can the necessity for washing be determined?

A. The presence of one or more short-circuited cells in a battery that has not been washed for some time will indicate the necessity for it. Each cell should be tested separately with the low-reading voltmeter; a short-circuited cell will either give no

voltage reading or one much below that of the others. Cut such a cell out and open it; if the short-circuit has been caused by an accumulation of sediment, the others most likely are approaching the same condition.

Q. How is a battery washed?

A. By cutting the cells apart, unsealing them, and lifting out the elements which should be immersed immediately in a wooden tub of clean pure water. The separators then are lifted out and the positive and negative groups of plates separated, but they must be marked so that the same groups may go back in the right cells. Before disposing of the old electrolyte, its specific gravity should be noted, as new electrolyte of the same density must be used. The plates should be washed in copious running water for several hours, but their surfaces must never be exposed to the air. Reassemble with new separators, fill the jars with fresh electrolyte of the same specific gravity as that discarded, and keep the elements under water until ready to place in the jars, which then should be sealed and the lead connectors burned together again.

Give a long slow charge after reassembling. The battery will not regain its normal capacity until it has been charged and discharged several times.

Connectors

Q. Why should lead connectors be employed, and why is it necessary to burn them together?

A. Any other metal will corrode quickly. Burning is necessary to make good electrical connection, except where bolted connectors are employed.

Q. When connections have become badly corroded or broken, what should be done with them?

A. They should be replaced with new lead-strap connectors supplied by the makers. If they are not obtainable and the battery must be in service meanwhile, the old ones can be cleaned by cutting away the corroded parts and burning new lead on them to bring them to normal size. If broken, burn together with lead in the same way. Heavy copper cable can be used temporarily but must be removed as soon as possible, as it will corrode quickly. Never use any other metal except lead or copper and never use light copper

wire. It will either be burned up in a flash or it will cut down the amount of current from the battery, thus causing unsatisfactory operation.

Buckled Plates

Q. What is the cause of badly disintegrated or buckled plates?

A. Sudden discharge due to a short-circuit or to constant abuse of the starting motor on an insufficiently charged battery.

Q. Is there any remedy for such a condition?

A. If the plates are not badly buckled and have not lost much of their active material, the cells may be put in service again by washing and reassembling as described, but if there is any considerable loss of active material, new plates will be necessary.

Low Battery

Q. What are the indications of a low battery?

A. The starting motor fails to turn the engine over, or does so very slowly, or only a part of a revolution. The lights burn very dimly. The hydrometer shows a specific-gravity reading of 1.250 or less. Voltmeter test shows less than 5 volts for a 3-cell battery (for greater number of cells, in proportion), or 1.75 volts or less for each cell.

Q. What are the causes of a low battery?

A. The electrolyte not covering the plates, or being too weak or dirty. A short-circuit in the battery due to the accumulation of sediment reaching the bottom of the plates. An excessive lamp load, all lights being burned constantly with but little daylight running the car. Generator not charging properly.

Specific Gravity; Voltage

Q. What are the specific gravity and voltage of fully discharged and fully charged cells?

A. Total discharge: 1.140 to 1.170 on the hydrometer; and 1.70 to 1.85 volts on the voltmeter. Fully charged: 1.276 to 1.300 specific gravity; 2.35 to 2.55 volts.

Q. Are these readings always constant for the same conditions?

A. No. The charging voltage readings will vary with the temperature and the age of the cell; the higher the temperature and the older the cell the lower the voltage will be. Hydrometer

readings also depend on the temperature to some extent. For every ten degrees Fahrenheit rise in temperature, the specific gravity reading will drop .003 or three points, and *vice versa.*

Q. Under what conditions should voltage tests be made?

A. Only when the battery is either charging or discharging. Readings taken when the battery is idle are of no value.

Q. Under what conditions should hydrometer tests be made?

A. The electrolyte must be half an inch over the plates and it must have been thoroughly mixed by being subjected to a charge. Hydrometer readings taken just after adding water to the cells are not dependable.

Q. When should acid be added to the electrolyte?

A. As the acid in a battery cannot evaporate, the electrolyte should need no addition of acid during the entire life of the battery under normal conditions. Therefore, if no acid has leaked or splashed out and the specific gravity is low, the acid must be in the plates in the form of sulphate and the proper specific gravity must be restored by giving the battery an overcharge at a low charging rate.

Q. What does a specific gravity in some cells lower than in others indicate?

A. Abnormal conditions, such as a leaky jar, loss of acid through slopping, impurities in the electrolyte, or a short-circuit.

Q. How can it be remedied?

A. Correct the abnormal conditions, and then overcharge the cells at a low rate for a long period, or until the specific gravity has reached a maximum and shows no further increase for 8 or 10 hours. If, at the end of such an overcharge, the specific gravity is still below 1.270, add some specially prepared electrolyte of 1.300 specific gravity. Electrolyte should not be added to the cells under any other conditions.

Q. Is an overcharge beneficial to a battery?

A. The cells will be kept in better condition if a periodical overcharge is given, say once a month. This overcharge should be at a low rate and should be continued until the specific gravity in each cell has reached its maximum and comparative readings show that all are alike. To carry this out properly will require at least 4 hours longer than ordinarily would be necessary for a full charge. If the plates have become sulphated due to insufficient

charging, it may be necessary to continue the overcharge for 10 to 15 hours longer. Should the specific gravity exceed 1.300 at the end of the charge, draw off a small amount of electrolyte with the syringe from each cell and replace with distilled water. If below 1.270, proceed as mentioned above for addition of acid.

Charging from Outside Source

Q. What is meant by charging from an outside source?

A. A source of direct current other than the generator on the car.

Q. Why is it necessary to charge the battery from an outside source?

A. When the battery has become sulphated, has been standing idle for any length of time, or has been run down from any other cause so that it is out of condition, a long charge at a uniform rate is necessary, and it would seldom be convenient to run the car for 8 or 10 hours steadily simply to charge the battery; frequently, a longer charging period than this is necessary.

Q. How is charging from an outside source effected?

A. This will depend upon the equipment at hand and the nature of the supply, i.e., whether alternating or direct current. If the current is alternating, a means of converting it to direct current is necessary, such as a motor-generator, a mercury-arc rectifier, chemical or vibrating type of rectifier. These are mentioned about in the order of the investment involved. In addition, a charging panel is needed to complete the equipment, this panel being fitted with switches, voltmeter, and ammeter, and a variable resistance for regulating the charge. Where direct-current service is obtainable at 110 or 220 volts, the rectifier is unnecessary.

Q. How can a battery be charged from direct-current service mains without a special charging panel?

A. By inserting a double-pole single-throw switch and 10- or 15-ampere fuses on taps from the mains and ordinary incandescent lamps in series with the battery to reduce the voltage, Fig. 480.

Q. How many lamps will be needed?

A. This will depend upon their character and size, as well as upon the amount of charging current necessary. For a 10-ampere charge for a 6-volt storage battery, seven 110-volt 100-watt (32

c.p.) carbon-filament lamps, or their equivalent, will be needed; i.e., fourteen 110-volt 50-watt (16 c.p.) carbon-filament lamps; eighteen 110-volt 40-watt tungsten lamps, or twenty-eight 110-volt 25-watt tungsten lamps. For a 12-volt or 24-volt battery the number of lamps will have to be decreased in proportion in order not to cut the voltage of the supply current below that of the battery. For 220-volt d.c. supply mains, if a three-wire system is employed, the taps should be taken from the center wire and one outside wire; this will give 110 volts. If the service is 220-volt two-wire, more lamps will be needed to reduce the voltage, which should exceed that of the battery by only 1½ to 2 volts, except where a high voltage charge to overcome sulphating is being given, in which case it may be slightly higher.

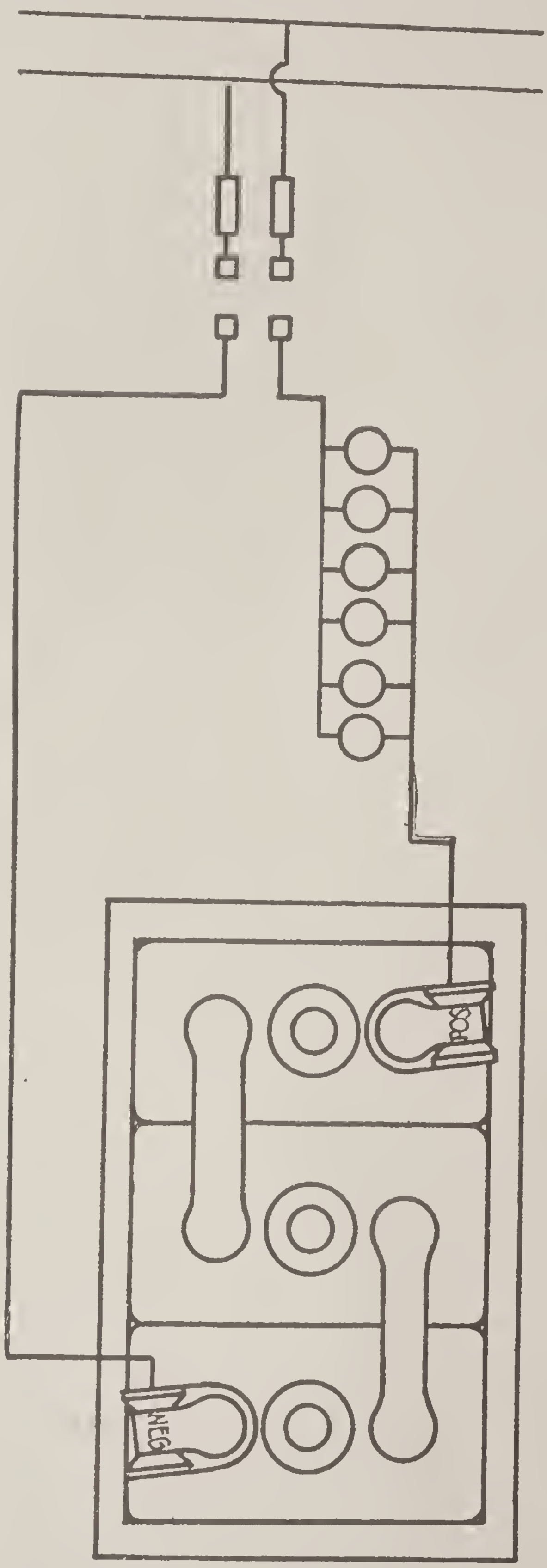


Fig. 480. Diagram of Connections for Charging Six-Volt Storage Battery from Lighting Circuit

Q. Where no outside source of current is available, or where no rectifier is at hand to convert alternating current, how can the battery be given the long charge necessary?

A. Run the engine. Supply it with plenty of oil and provide hose connections from the water supply to the filler cap on the radiator and a drain from the lower petcock. Open the latter and turn on just sufficient water to keep the engine reasonably cool; increase if necessary as it runs hotter.

Q. What precaution must be taken always before putting the battery on charge from an outside source?

A. The polarity of the circuit must be tested in order to

make certain that the battery will be charged in the proper direction.

Q. How can this be done?

A. If a suitable voltmeter is at hand, i.e., one of the proper voltage for the 110-volt current, connect it to the mains. If the needle does not move over the scale but shows a tendency to butt against the stop pin at the left, reverse the connections. The needle will then give a proper reading and the positive connection to the meter must be used for the positive side of the battery. Should no voltmeter of the right voltage be available, connect two short wires with bared ends to the fused end of the switch. Dip the bared ends of the wire in a glass of water, being careful to keep them at least an inch apart. When the switch is closed, fine bubbles will be given off by the wire connected to the negative side. The battery terminals are stamped *Pos.* and *Neg.*, and the connections should be made accordingly.

Intermittent and Winter Use

Q. What should be done with an idle battery?

A. If it is to be idle for any length of time, as where the car is to be stored, it should be given a long overcharge as described above before being put out of service. Fill the cells right to the top with distilled water to allow for evaporation and absorption of acid by the plates. Give the battery a freshening charge at a low rate once a month. Discharge the battery and re-charge before putting it into service again. If it has stood out of service for a long period, the battery will be found at a low efficiency point and will not reach its maximum capacity again until it has had several charges and discharges.

Q. Does cold weather have any effect on the storage battery?

A. It causes a falling off in its efficiency. If not kept charged, the electrolyte will freeze under the following conditions: battery fully discharged, sp. gr. 1.120, 20° Fahrenheit; battery three-quarters discharged, sp. gr. 1.160, temperature zero; half discharged, sp. gr. 1.210, 20 degrees below zero; one quarter discharged, sp. gr. 1.260, 60 degrees below zero. When storing away for the winter, the battery must either be kept charged or put where the temperature does not go lower than 20 degrees above zero.

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